THE GEOGRAPHY OF THE OCEANS

BY

J. F. WILLIAMS, F.R.G.S.

ATLASES, MAPS, & CLASS-BOOKS,

PUBLISHED BY

GEORGE PHILIP AND SON.

SERIES OF SCHOOL ATLASES,

EDITED BY WILLIAM HUGHES, F.R.G.S.

	s.	d.
PHILIPS' PREPARATORY ATLAS, containing 16 Maps. Crown 4to, full colored, in neat cover ...	0	6
PHILIPS' PREPARATORY OUTLINE ATLAS. 16 Maps. Crown 4to, in neat cover	0	6
PHILIPS' PREPARATORY ATLAS OF BLANK PROJECTIONS. 16 Maps. Crown 4to, in neat cover	0	6
PHILIPS' STANDARD ATLAS. 24 Maps, colored. Foolscap 4to, in neat cover	0	6
PHILIPS' ELEMENTARY ATLAS. 16 Maps, full colored. Small 4to, in neat cover	0	6
PHILIPS' ELEMENTARY OUTLINE ATLAS. 16 Maps. Small 4to, in neat cover	0	6
PHILIPS' INITIATORY ATLAS FOR YOUNG LEARNERS. 12 Maps. 16mo, plain, 3d.; colored...	0	6
PHILIPS' FIRST SCHOOL ATLAS. New and enlarged edition. Containing 24 Maps, full colored, bound in cloth	1	0
PHILIPS' SHILLING ATLAS OF MODERN GEOGRAPHY. 12 Maps. Imp. 4to, illustrated cover ...	1	0
PHILIPS' ATLAS FOR BEGINNERS. New and improved edition, with Index. Crown 4to, cloth	2	6
PHILIPS' HANDY SCHOOL ATLAS. 32 Maps, with Consulting Index. Crown 8vo, cloth, lettered	2	6
PHILIPS' YOUNG SCHOLAR'S ATLAS. New edition. Containing 24 Maps. Imperial 4to, bound in cloth ...	2	6
PHILIPS' YOUNG STUDENT'S ATLAS. New edition. Containing 36 Maps. Imperial 4to, bound in cloth ...	3	6
PHILIPS' INTRODUCTORY SCHOOL ATLAS. 18 Maps, with Consulting Index. New edition. Imperial 8vo, bound in cloth...	3	6

George Philip and Son, Publishers, London and Liverpool.

SERIES OF SCHOOL ATLASES—Continued.

	£	s.	d.
PHILIPS' SELECT SCHOOL ATLAS. 24 Maps, with Consulting Index. New and improved edition. Imperial 8vo, bound in cloth		5	0
PHILIPS' STUDENT'S ATLAS. Containing 38 Maps, with Index. Imperial 8vo, strongly bound in cloth ...		7	6
PHILIPS' COMPREHENSIVE SCHOOL ATLAS, containing 37 Modern and 7 Ancient Maps, with Index. Imperial 8vo, strongly half-bound, cloth sides		10	6
PHILIPS' PHYSICAL ATLAS FOR BEGINNERS. 12 Maps. Crown 4to, in stiff cover		1	0
The same Book, bound in cloth, lettered		1	6
PHILIPS' SCHOOL ATLAS OF PHYSICAL GEOGRAPHY. Imperial 8vo, bound in cloth		10	6
HUGHES' TRAINING SCHOOL ATLAS, a series of 16 Physical Maps. Med. fol., cloth, lettered		15	0
PHILIPS' SCHOOL ATLAS OF SCRIPTURE GEOGRAPHY, 12 Maps. Crown 4to, stiff cover		1	0
The same Book, bound in cloth, lettered		1	6
PHILIPS' SMALLER SCRIPTURE ATLAS. 12 Maps, illustrated cover, 6d.; cloth, lettered		1	0
PHILIPS' SCHOOL ATLAS OF CLASSICAL GEOGRAPHY, 18 Maps, with Consulting Index of Ancient and Modern Names. Med. 4to, cloth		5	0
PHILIPS' HANDY CLASSICAL ATLAS. Containing 18 Maps. Med. 8vo, bound in cloth		2	6
PHILIPS' SCHOOL ATLAS OF AUSTRALIA. Crown 4to, bound in cloth		2	0
PHILIPS' SCHOOL ATLAS OF NEW ZEALAND. Crown 4to, cloth		2	0
PHILIPS' IMPERIAL ATLAS OF OUTLINE MAPS. Two Series, each containing 12 Maps, in cover, each ...		1	0
PHILIPS' IMPERIAL ATLAS OF BLANK PROJECTIONS. Two Series, each containing 12 Maps, in cover, each		1	0
PHILIPS' OUTLINE ATLAS FOR BEGINNERS. Two Series, each containing 16 Maps, neat cover, each		1	0
PHILIPS' BLANK PROJECTIONS FOR BEGINNERS. Two Series, each containing 16 Maps, cover ...		1	0

CONTOUR-MAP OF THE OCEANS.

George Philip & Son London & Liverpool

Depth in fathoms: under 1000 | 1000 - 2000 | 2000 - 3000 | 3000 & below

THE GEOGRAPHY

OF

THE OCEANS,

PHYSICAL, HISTORICAL, AND DESCRIPTIVE.

BY

J. FRANCON WILLIAMS, F.R.G.S.

WITH MAPS AND ILLUSTRATIONS.

LONDON:
GEORGE PHILIP & SON, 32 FLEET STREET.
LIVERPOOL: CAXTON BUILDINGS, SOUTH JOHN STREET;
AND 49 & 51, SOUTH CASTLE STREET.
1881.

[*All Rights Reserved.*]

PREFACE.

This little treatise must be regarded only as an attempt to present the leading facts of the "Geography of the Oceans" in a simple and systematic manner, and is mainly intended for the use of Students who have to pass a special examination in this subject. It may also be useful to those who wish to supplement their general geographical knowledge, which is ordinarily limited to the Physical and Political Geography of the Countries of the World, by an acquaintance with the main facts relative to the "great world of waters."

January, 1881.

CONTENTS.

PART I.

GENERAL GEOGRAPHY OF THE OCEANS.

	Page
I.—Introduction	1
II.—The Distribution of Land and Water ...	5
III.—The Divisions of the Ocean	9
IV.—Oceanic Intercommunication	13
V.—Oceanic River-Systems	18
VI.—Navigation and Progress of Discovery	24

PART II.

PHYSICAL GEOGRAPHY OF THE OCEANS.

I.—Introduction	31
II.—The Salts of the Sea	33-42
Composition of Sea Water	33
The Salts of the Sea—whence derived, and how their uniform proportion is maintained ...	37
Results of the Saltness of the Sea	41
III.—The Density, Colour, and Phosphorescence of the Sea	43-47
Density of Sea-water	43
Colour and Phosphorescence of the Sea ...	46

	Page
IV.—Depth of the Ocean, and form of Sea-bottom	48-61
Depth of the Ocean—Deep-sea Soundings ...	48
" " —Theory of Waves ...	53
" " —General Results... ...	54
Pressure and Weight of the Ocean ...	55
Form of Sea-bottom	57
V.—Distribution of Marine Life	62-67
Distribution of Marine Vegetable Life ...	62
Horizontal Distribution of Marine Animal Life	63
Vertical Distribution of Marine Animal Life ...	65
VI.—Temperature of the Ocean	68-72
Introduction	68
Temperature—Horizontal and Vertical ...	69
VII.—Movements of the Ocean	73-78
Introduction	73
Atmospheric Movements or Waves	74
Waves—Nature of Motion	75
Different aspects of Waves	76
Waves—their Magnitude, Velocity, and Force	77
VIII.—Sidereal Movements or Tides	79-85
Tides—Lunar and Solar	79
Tidal-wave—Formation, Direction, and Velocity	84
IX.—Proper Movements or Currents	86-99
Introduction	86
Classification of Currents	88
General View of the Currents of the Ocean	90
Oceanic Circulation	92
Ocean Currents—influence of the Earth's Rotation	96
Ocean Currents—Temperature and Velocity...	98
X.—Influence of the Sea on the Distribution of Climate	100-105
XI.—Action of the Sea on the Earth's Crust	106-115
The Sea as an Agent of Destruction ...	110
The Sea as a Reproductive and Preservative Agent	113

PART III.

THE GEOGRAPHY OF PARTICULAR OCEANS.

	Page
I.—The Atlantic Ocean	119-164
Boundaries and Extent	119
Islands	122
Seas, Bays, and Gulfs	123
Straits and Channels	125
General Character of Coasts	126
River Systems	130
Currents	133
Depth and Configuration of its Bed ...	141
Navigation and Commerce	143
Historical Notes	152
Notes on the Principal Seas belonging to the Atlantic :—The Baltic, Mediterranean, Black Sea	157
The Caspian Sea	163
II.—The Pacific Ocean	165-187
Boundaries and Extent	165
Islands	167
Seas, Bays, Gulfs, Straits, and Channels ...	169
General Character of Coasts	171
River Systems	172
Currents	174
Depth and Configuration of its Bed ...	178
Navigation and Commerce	180
Historical Notes	184
III.—The Indian Ocean	188-207
Boundaries and Extent	188
Seas, Bays, &c.	189
River Systems	191
General Character of Coasts	193
Principal Currents, Depth, and Form of its Basin	193
Navigation and Commerce	199
Historical Notes	204

Page.

IV.—The Antarctic Ocean 208–218
Generalities 208
Historical Notes 211
V.—The Arctic Ocean 219
Generalities 219
Historical Notes 226

LIST OF MAPS AND CHARTS.

Contour-Map of the Ocean ... ... *Frontispiece*
Continental and Oceanic Hemispheres ... ... *To face page* 7
Divisions of the Ocean... ... ... " 9
Approximate Sections of the Atlantic and Pacific " 61
Chart of Co-tides ... ... " 84
„ Ocean-Currents ... ... " 89
The Atlantic Ocean ... ... " 119
The Pacific Ocean ... ... " 165
The Indian Ocean ... ... " 188
The Arctic and Antarctic Oceans ... ... " 208

I.

GENERAL GEOGRAPHY

OF THE

OCEANS.

I.

INTRODUCTION.

1. Although it may be taken for granted that the various terms which we shall have occasion to use in the following pages are already sufficiently familiar to the student, yet, bearing in mind that nothing is so important in scientific description as exactness and accuracy of meaning and application of the terms used, it will be necessary to furnish the student with more precise definitions than are generally given. Many of the terms are simple, it is true, but several of them have a peculiar significance of meaning, which is too frequently overlooked, and thus wrong impressions are formed by the loose application of apparently simple terms.

2. Viewing the earth as a whole, we find its outer crust characterized by extremely irregular elevations and depressions—the more elevated portions constituting the land masses, while the considerably depressed portions form the receptacle for a vast body of water, configured by the intervening masses of land into certain more or less definite areas, called oceans. Generally speaking, the waters of the ocean cover every part of the earth's outer crust up to a certain fixed limit called the *sea-level*.

3. But, besides the extreme irregularity in elevation, there is also, as a glance at a map of the World will show, a corresponding irregularity in horizontal configuration, the latter being, in fact, a result of the former. Even a cursory examination of the contour[1] of the great land masses will convince the student that the "line of contact" between the sea and the land is not mathematically precise. In some parts the coast-line is regular and unbroken, but generally quite the reverse, the sea penetrating into or actually intervening between the masses of land in an endless variety of ways. And although with a few exceptions, the great waters of the globe form one continuous and connected expanse, the irregularity of the line of contact with the land necessitates the use of various terms, showing the mutual relations, as to position and extent, of the sea and the land.

Definitions.

4. The vast collection of water which surrounds the land in every direction is commonly called the "Sea," and is really continuous and indivisible. The intervention of the great land-masses, however, is such that the sea can be conveniently divided into five more or less definite areas called oceans. It may be here remarked that the terms "ocean," "sea," are often used synonymously and applied indiscriminately to the great "world of waters" as a whole. But, *geographically*, the term *ocean* is limited to the largest divisions of water, and *sea* to smaller areas, entirely separated from, or broadly uniting with, the larger expanses called oceans. A gradual bend in the coast-line forms a *bay*,[2] but if the sea penetrates into the land for any considerable distance, a *gulf*[3] is formed. Smaller indentations form *creeks*,[4] *harbours*,[5] *firths*, *fiords*, and other

[1] *Contour* (Fr.), outline or turn. "The contour of a continent or island is simply the delineation of the line of contact between the lands and the horizontal surface of the oceans."—Guyot, *Earth and Man*.

[2] *Bigan* (A. S.), to bend.

[3] *Kolpos* (Gr.), a fold.

[4] *Crecca* (A. S.), a corner.

[5] From *herberge*, a resting-place.

variously-named *inlets*. A shallow body of salt water close to the sea, separated entirely or nearly so from it by a low sandy ridge, is called a *lagoon*[1] or *haff*.[2] Any considerable collection of salt water, surrounded or nearly so by land, are termed *inland seas*. The channels of communication between the larger bodies of water are also distinguished as *straits*,[3] if narrow and of no great length, or *channels*[4] if of greater length and width. The narrow arms of water between islands and the mainland are called *sounds*.[5]

5. It will be readily perceived that while most of the above terms are exact and of general application, several are synonymous, and others are local, being restricted to certain countries. Thus the terms *firth* or *frith*, *lough*, *loch*, *fiord*, &c., are synonymous in many cases, but the terms "firth," "loch," are restricted to Scotland; "lough" to Ireland; "fiord" to Norway. There is this further distinction, that "loch," in Scotland, is applied to narrow inlets of the sea as well as to actual lakes. The same may be said of "lough," in Ireland. The term "firth," or "frith," on the contrary, is restricted to arms of the sea, generally those receiving large rivers, and thus is equivalent to the term "estuary" in England and elsewhere. "Fiord," or "fjord," is indiscriminately applied to narrow inlets, and is peculiar to Norway and Denmark. The term "haff," again, is only used on the Prussian Baltic coast, "lagoon" being the equivalent term in the south of Europe and America.

6. The various movements of the ocean are distinguished as (1) *currents*,[6] or an onward motion of the water in certain localities, aptly described as "rivers in the ocean;" (2) *waves*,[7] *billows*,[8] and other surface-disturbances due to the action of winds and storms; (3) *tides*,[9] or the regular rising and falling

[1] *Lacuna* (Lat.), anything hollow.
[2] *Haff* means bay.
[3] *Strictus* (Lat.), drawn together.
[4] *Canalis* (Lat.), a water-pipe.
[5] *Sund* (A. S.), an arm of the sea.
[6] *Currens* (Lat.), running.
[7] *Wegan* (A. S.), to move.
[8] *Belgan* (A. S.), to swell.
[9] *Tid* (A. S.), time.

of the water produced by lunar and solar attraction. A tidal-wave rushing up a narrow strait or estuary frequently forms a *bore* or *aegre*.

7. The irregularity of the bottom of the sea, apparently elevated and depressed like the land, gives rise to *banks*, *shoals*, *roads* or *roadsteads*, *harbours*, *pits*, *deeps*, *troughs*, *basins*, *submarine ridges*, &c.

[In order to fix in the memory the exact meaning of the various terms detailed in the preceding chapter, the student would do well to supplement the definitions given by selecting a few actual examples of each, and entering them in order in his note-book. Speaking of the importance of the proper use of geographical terms, Dr. Page remarks that "there is nothing so essential in scientific description as clearness and precision, and this can only be obtained by employing for the object described the term by which it is known, and this in such a way that it cannot be confounded with any other object, or mistaken for something else. Precise writing need not be dry reading; on the contrary, it is a loose description that soonest fatigues, and leaves, in the long run, the least satisfactory impression."]

II.

THE DISTRIBUTION OF LAND AND WATER.

Relative Areas and Position.

8. We have already noticed the characteristic irregularities of the earth's outer crust as regards *elevation* or *relief*. The same extreme irregularity is also apparent in the configuration or *contour* of the land masses, a result of the irregular distribution of land and water. A careful examination of a map of the World or an artificial globe will show that the main element in this irregular distribution is the preponderance of land in the northern hemisphere; and, *vice versa*, the vastly greater extent of water in the southern hemisphere. In round numbers, the actual and relative extent of land and water in the northern and southern hemispheres are as follows:—

NORTHERN HEMISPHERE.

Land.....38,000,000 square miles Water .....60,500,000 „	}	In the ratio of 1 : 1.5

SOUTHERN HEMISPHERE.

Land.....13,500,000 square miles Water .....85,000,000 „	}	In the ratio of 1 : 6.3

Were it necessary to illustrate this proportion by a map, we should have to take the north pole[1] as a centre for the northern hemisphere, and the south pole as a centre for the southern hemisphere, the radius in each case being 90° of latitude—the equator, of course, being the circumference. This arrangement

---

[1] *Polos* (Gr.), the end of an axis.

not being frequently given in general atlases, the student would do well to construct a map of the world, showing the northern and southern hemispheres, for his own use.

9. The projection most commonly used in maps of the world is that of two hemispheres, the eastern and the western, the dividing line being a great circle drawn round the globe at a point 20° W. long. This purely arbitrary division is nevertheless the most convenient for general purposes, showing as it does the whole of the three continents of the Old World in the eastern, and the two continents of the New World in the western, hemisphere. The distribution of land and water, thus considered, is also very irregular, land predominating in the eastern, and water in the western, hemisphere. In round numbers, the actual and relative areas are as follows :—

EASTERN HEMISPHERE.

Land.....35,500,000 square miles Water .....64,000,000 „	}	In the ratio of 1 : 1.8

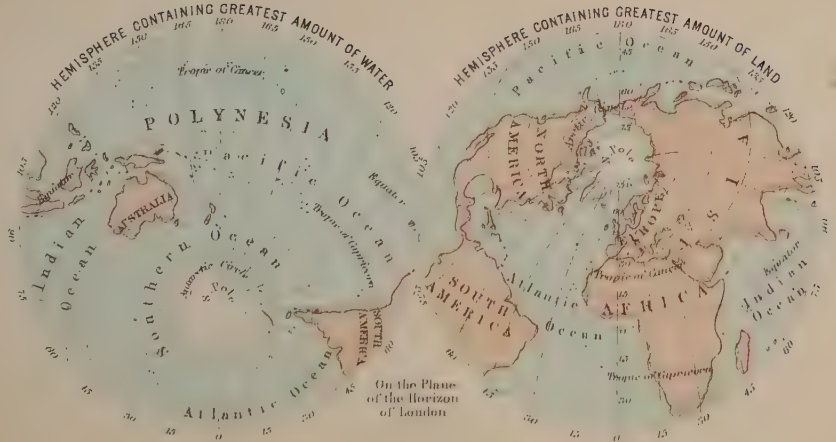
WESTERN HEMISPHERE.

Land.....16,000,000 square miles Water .....81,500,000 „	}	In the ratio of 1 : 5

10. But the irregularity of the distribution of land and water is, perhaps, most strikingly shown by projecting two hemispheres, the one having London for its centre, the other Antipodes Island. The former will be found to include all the great continental land masses, with the exception of a part of South America, Australia, and adjoining islands, and may therefore be called the *continental*[1] or *land hemisphere*, while the latter is nearly all occupied by water, and may be called the *oceanic* or *water hemisphere*. In round numbers, the actual and relative areas of the continental and oceanic hemispheres are as follows :—

[1] *Con* (Lat.), together, and *teneo*, I hold.

To face page 7.



CONTINENTAL OR LAND HEMISPHERE.

Land.....44,000,000 square miles
Water .....54,000,000 „ } In the ratio of 1 : 1.2

OCEANIC OR WATER HEMISPHERE.

Land..... 8,000,000 square miles
Water .....90,500,000 „ } In the ratio of 1 : 11.3

11. Although London is not the actual centre of a hemisphere that shall include the greatest possible proportion of the land of the globe—the exact centre being a point in the St. George's Channel, midway between the English and Irish coasts—yet it is sufficiently near, that it may be considered as the centre of the whole habitable world. The geographical position of the metropolis as a centre, round which cluster all the great continents, marks it out as a centre of universal influence, and the empire of which it is the capital is indeed paramount in power, wealth, and influence—first in rank among the nations of the world.

12. If we consider the relative proportions of land and water in the different zones,[1] we find the largest area of land occurs in the North Temperate Zone. An estimate[2] of the actual and

[1] From *Zone* (Gr.), a belt or girdle.

[2] This estimate is based on the calculations kindly furnished by Mr. J. Bartholomew, the eminent geographer, of Edinburgh. The actual numbers given by Mr. Bartholomew are as follows:—

LAND AND WATER ACCORDING TO ZONES.
AREA IN SQUARE MILES.

Zones.	Land.	Water.	Total Area of each Zone
North Frigid	2,598,583	5,576,917	8,175,500
North Temperate	25,147,688	25,973,812	51,121,500
Torrid	19,408,621	58,997,379	78,406,000
South Temperate	4,333,770	46,787,730	51,121,500
Total Land.....	51,488,660	137,335,838	188,824,500
South Frigid, unascertained..	..	8,175,500	8,175,500
Total Water	..	145,511,338	197,000,000

relative areas of land and water in the different zones gives the following results :—

	Land.	*Water.*	*Ratio.*
North Frigid Zone	2,600,000 ...	5,550,000	...1: 2.13
North Temperate Zone ...	25,150,000 ...	25,950,000	...1: 1.03
Torrid Zone	19,400,000 ...	59,000,000	...1: 3.04
South Temperate Zone ...	4,300,000 ...	46,800,000	...1:10.88
South Frigid Zone	*Unknown.*		

13. Generally speaking, then, of a total superficial area of 197,000,000 square miles, about 51,500,000 are land, and 145,500,000 water—the former comprising *one-fourth*, the latter *three-fourths* of the earth's surface. The most striking feature in this terraqueous arrangement, as we have already observed, is the predominance of land in the Northern, and of water in the Southern, Hemisphere. It will also be seen that the northern coasts of Europe, Asia, and America, almost encircle the north polar area, while the south polar regions are entirely surrounded by the vast expanse of the Southern Ocean. There are many other striking facts connected with the arrangement of land and water—such as the analogies and contrasts in form and disposition of the various land masses, &c. These we need not specify here, as the student can readily discover them on examination of a map of the world. We cannot, it is true, account for the present distribution of land and water—we only know that it is not the same as in former geological periods; for we have ample proofs that "continents existed where seas now roll, and seas extended where continents are now established."

[Further particulars of the distribution of land and water, and the results of probable changes, will be found in Appendix A.]

Chart showing
PRINCIPAL DIVISIONS OF THE OCEAN

George Philip & Son London & Liverpool.

III.

DIVISIONS OF THE OCEAN.

14. Although the waters of the ocean form one vast continuous and naturally indivisible body, they are configured by the intervention of the great land masses into five more or less well-defined areas. Thus we have the *Atlantic*[1] *Ocean*, between the Old World on the east and the New World on the west; and the *Pacific*[2] *Ocean*, between the Old World on the east and the New World on the west. The great land masses broadening out towards the North Pole, and tapering to points towards the south, we have a vast expanse of water girdling the earth between the southern extremities of Australia, Africa, and America, and the Antarctic Circle, to which the name *Southern Ocean* has been given. The portion north of this vast area, limited by the coasts of Eastern Africa, Southern Asia, and Western Australia, forms the *Indian*[3] *Ocean*. The circum-polar seas, theoretically bounded by the Arctic and Antarctic circles, are also distinguished as the *Arctic*[4] and *Antarctic*[5] *Oceans*. The name 'Southern Ocean' is given, as we have said, to the vast expanse of water in the Southern Hemisphere south of the Cape of Good Hope and Cape Horn. *Geographically*, however, no such division is

---

From *Mt. Atlas* in N.W. Africa.

[2] *Pacificus* (Latin, peaceful). So called by Magellan because of its "peacefulness" compared with the boisterous waters of the Atlantic.

[3] From its proximity to *India*.

[4] *Arktos* (Gr.), the bear, or the north.

[5] *Anti* (Gr.), opposite to; and *arktos*, the north.

recognised, the Atlantic, Pacific, and Indian Oceans being supposed to extend as far south as the Antarctic Circle. But the term 'Southern Ocean' is both convenient and useful, especially in treating of oceanic circulation, and the phenomena of tides and tidal waves. Geographical writers, also, distinguish the Atlantic and Pacific north and south of the Equator, as *North* and *South Atlantic*, and *North* and *South Pacific*, Oceans, respectively.

15. The Atlantic Ocean extends from the Arctic Circle on the north to the Antarctic Circle on the south, having the western coasts of Europe and Africa as its eastern, and the eastern coasts of North and South America as its western, limits. Its comparatively little interruption by islands, its vast currents, and a greater length of coastline than all the other oceans together, are some of the distinguishing features of the Atlantic Ocean. Its division by the Equator into the North and South Atlantic also marks a change in its configuration—its northern shores being extremely irregular, the land on either side being deeply indented; while south of the Equator its coastline is, on the whole, regular and unbroken. Communication with the Arctic Ocean on the north is limited to an expanse of about fifty degrees in width between Greenland and Norway, (divided by Iceland into two unequal channels), and by Davis Strait and Baffin Bay; while on the south it opens out broadly into the Antarctic Ocean. The principal inlets belonging to the Atlantic are;—*On its eastern side*—the North Sea, (connected by the Skager Rack and Cattegat with the Baltic Sea), the English Channel, Irish Sea, St. George's Channel, Bay of Biscay, the Mediterranean, (connected by the Dardanelles and the Sea of Marmora with the Black Sea and Sea of Azov), and the Gulf of Guinea. *On its western side*—Davis Strait, leading into Baffin Bay, Hudson Bay and connecting channel, Gulf of St. Lawrence, Bay of Fundy, Gulf of Mexico, and the Caribbean Sea.

16. The Pacific Ocean extends from the Arctic Circle on the north to the Antarctic on the south, the western shores of America forming its eastern, and the eastern coasts of Asia and Australia its western, limits. The Pacific, though nearly twice as large as the Atlantic, is not by any means as important. Its principal characteristic is the vast number of islands with which it is studded. The configuration of its opposite shores differ considerably—the *eastern* or American side being penetrated only by the Gulfs of California and Panama; while the *western* side shows a number of considerable indentations forming the Sea of Kamtchatka, Gulf of Okhotsk, Sea of Japan, Yellow Sea, China Sea.

17. The Indian Ocean extends from the southern coasts of Asia on the north to the Antarctic Circle on the south, having Eastern Africa and a portion of the Atlantic as its *western*, and the Malay Archipelago and Western Australia as its *eastern*, boundaries. Unlike the Atlantic and Pacific Oceans, which penetrate the land mostly on their eastern and western sides, the only considerable indentations belonging to the Indian Ocean are all on its *northern* boundary, the principal being the Bay of Bengal, Arabian Sea, Persian Gulf, and Red Sea. With the exception of the Malay Archipelago, which forms its boundary on the east, the Indian Ocean does not contain many islands, the largest being Madagascar, off the African coast, from which it is separated by Mozambique Channel.

18. The Arctic Ocean is almost circumscribed by the northern coasts of America, Europe, and Asia. It encroaches on Europe in the White and Kara Seas; on Asia in the Gulf of Obi, Anabarski Gulf, and other smaller inlets; on America in a number of channels and bays, such as Baffin Bay, (connected by Davis Strait with the Atlantic), Lancaster Sound, Barrow Strait, Melville Sound, Gulf of Boothia, &c., which are frozen during the greater part of the year. Navigation in

the Arctic Sea is at the best difficult and dangerous, and although many expeditions have been sent out with the express object of reaching the north pole, all have failed; the furthest northern point being attained by Captain Markham in 1876. Our knowledge of the Arctic basin is thus imperfect, and the existence of an open sea or ice-bound land at the North Pole is not likely to be ever satisfactorily proved.

19. The Antarctic Ocean is the name given to the body of water comprised within the Antarctic Circle. Its boundaries are of course purely imaginary, its waters merging indefinitely into the southern expanses of the Pacific, Atlantic, and Indian Oceans. This ocean has not been explored with the same persistency as the Arctic, nor has such a high latitude ever been reached, its navigation being even more difficult and dangerous. The portions of land already discovered in various localities bordering on and within the Antarctic Circle renders it highly probable that a vast continent surrounds the South Pole.

[As regards the derivation and application of special names to the principal divisions of the sea, we may state that the *Atlantic Ocean* was so called at a very early period, probably from the range of Mt. Atlas, in North Africa. The *Pacific Ocean* received its designation in 1520, being so called by Magellan, from the fine weather he experienced while crossing it. The *Indian Ocean*, undoubtedly, was so called from the proximity of India, but when is uncertain. The *Arctic* and *Antarctic Oceans* are comparatively modern terms, for it was not until the tenth and fifteenth centuries respectively that they were approached. Both names are from the Greek, *arktos*, the bear, or the north; the prefix *anti* distinguishing the *south* from the *opposite* north polar ocean.]

IV.

OCEANIC INTERCOMMUNICATION.

20. It is scarcely necessary to draw the attention of the student to the importance of a clear conception of the actual and relative position of the great oceans and minor seas. This, in fact, is indispensable; otherwise, no matter what amount of information may be acquired, it will be more or less vague and indefinite. The mutual relations of the more important parts of the "world of waters," may perhaps be most easily and clearly perceived by a systematic consideration of what we have ventured to call "oceanic intercommunication." Let us then proceed to observe, first, how the great oceans communicate with one another; and, secondly, the connection between each ocean and the minor seas, &c., belonging to it.

21. The Atlantic Ocean, lying between the two greatest longitudinal expanses of land, is open only on the north and south. On the north it communicates with the *Arctic Ocean* by two channels of unequal width; Davis Strait, between Cumberland Island and Western Greenland, and the wider channel between East Greenland and Norway. But while communication northwards is thus comparatively limited, the South Atlantic opens out broadly into the *Antarctic Ocean.* At 35° S. lat. the definite boundary formed by the African coast ceases; thence to the Antarctic an imaginary line, along the line of 20° W. long., forms the theoretical limit between the Atlantic and Indian Oceans. Thus the communication on the east with the *Indian Ocean* is perfectly

open for 31½ degrees. We may also remark that there is now actual communication between the Atlantic and Indian Ocean by the Mediterranean, Suez Canal, and the Red Sea. The western side of the South Atlantic is definitely limited by the South American coast as far as 55° S. lat., and a line drawn thence along the meridian of Cape Horn to the Antarctic Circle forms an imaginary boundary between the South Atlantic and Pacific Oceans, which thus communicate by the channel between Tierra del Fuego and South Shetland, as well as by Magellan's and other straits between the islands of Tierra del Fuego.

22. The limit (the Antarctic Circle) between the South Atlantic and the *Antarctic Ocean* is, of course, purely imaginary, there being only one natural boundary—Graham Land. With this exception the communication between the Atlantic and Antarctic is perfectly open, the one merging indefinitely into the other. Besides the channel already referred to, there is no direct communication between the Atlantic and the *Pacific Ocean*. Hence the expeditions sent out to discover a "north-west passage" into the Pacific through some of the numerous channels in the Arctic Archipelago. Captain McClure solved the problem in 1850, but the generally icebound state of the channels by which alone the passage can be made has rendered the discovery practically of no value. The narrowness of the isthmus connecting North and South America induced the idea of joining the two oceans by a canal, which will most probably be made before long.

23. The communication between the minor seas belonging to the Atlantic and the ocean itself is generally good—the channels in each case, though often of no great width, being sufficiently deep to allow the passage of the largest vessels. It must be borne in mind that the inland seas, &c. mentioned in this paragraph, belong entirely to the North Atlantic, there being no inland ramifications of the South Atlantic, nor even any considerable indentation, except the Gulf of Guinea.

Between Great Britain and the north-western coasts of the Continent lies the North Sea or German Ocean, connected with the Atlantic directly on the north, and indirectly on the south, by means of the *English Channel.* The North Sea is also connected with the Baltic by the *Cattegat* and the *Skager Rack.* The Irish Sea, between Ireland and the opposite Scotch and English coasts, is connected with the Atlantic on the north by the *North Channel*, and on the south by *St. George's Channel.* The *Straits of Gibraltar* admit of direct communication between the Atlantic and its largest inland sea—the Mediterranean,—which is again connected with the Black Sea by the *Dardanelles*, Sea of Marmora, and the *Bosphorus*, and, by means of the canal across the isthmus of Suez, with the Red Sea, and thus with the Indian Ocean.

24. On its western side the North Atlantic is connected with the Polar Seas by *Davis* and *Hudson's Straits;* the former opening directly into Baffin Bay, the latter into Hudson Bay. The Gulf of St. Lawrence communicates with the Atlantic on the north by *Belleisle Strait*, on the south by the *Gut of Canso*, and on the east by a wider channel between Cape North (Cape Breton I.) and Cape Ray (Newfoundland). The Mexican Gulf sends out a vast current into the Atlantic through the *Straits of Florida*, having admitted the inflow through the *Channel of Yucatan.* The Caribbean Sea communicates with the ocean by a number of channels between the various West Indian Islands—the principal being the *Windward Pass*, between Cuba and Hayti; *Mona Pass*, between San Domingo and Porto Rico, thence to Trinidad by numerous straits and "passes" between the Lesser Antilles.

25. The Pacific Ocean, unlike the Atlantic, which has a comparatively free communication with the Arctic Sea, is almost entirely landlocked on the north—the extreme eastern part of Asia approaching so closely to the extreme western part of North America that they are separated only by a narrow

channel, Behring's Strait. On the contrary, on the south it is perfectly open from Australia to South America, its waters merging broadly into those of the Antarctic Ocean. Direct communication with the *Atlantic* is possible in the south through the channel between Tierra del Fuego and South Shetland, or by the Straits of Magellan,—the indirect communication to the north, through Behring's Strait, by the "North-west Passage," has been already noticed, as also the probable artificial communication by the Panama Canal. The *Indian Ocean* communicates directly with the Pacific by a wide expanse of perfectly open water, stretching from Tasmania to the Antarctic Circle, the imaginary boundary-line being the meridian of South-West Cape of Tasmania. Indirectly, communication between these two oceans is possible by the numerous channels and seas of the Malay Archipelago, the principal being by (1) Torres Strait and Arafura Sea, between North Australia and New Guinea; (2) Gilolo Pass and Molucca Pass, Banda Sea, Flores Sea, and the straits between Timor, Ombay, and Flores; (3) Celebes Sea, Strait of Macassar, Java Sea, and Lombok, Sunda and other straits; (4) Channel of Formosa or Sulu Sea, China Sea, and Straits of Malacca. Of minor ramifications the principal are the Sea of Okhotsk or Kurile Sea, prevented from uniting broadly with the ocean by a chain of islands stretching from Japan to Kamschatka. The Sea of Japan communicates with the ocean by the Straits of Corea, Bungo Channel, Straits of Sangar and Le Perouse, and by the Gulf of Tartary on the north, uniting its waters with those of the Kurile Sea. The Yellow Sea unites directly with the ocean, while the China Sea communicates with it by the Strait and Channel of Formosa. On the north the Sea of Kamschatka or Behring's Sea is, like the Kurile Sea, separated from the open ocean by a chain of islands, the Aleutian Islands.

26. The northern portion of the Indian Ocean is land-locked on all sides except towards the south, where it opens

out broadly into the *Antarctic Ocean*, from which it is only partially separated by natural limits, such as Enderby Land, Kemp Land, and Clarie Land. The only considerable inland expanses belonging to the Indian Ocean are the Red Sea, connected with it by the Strait of Bab-el-mandeb and the Gulf of Aden; the Persian Gulf, connected by the Strait of Ormuz and the Gulf of Oman, the Arabian Sea, and the Bay of Bengal. It communicates freely with the *South Atlantic*, the limiting line south of Cape Agulhas being the meridian of 20° E. long., and with the *South Pacific* between Tasmania and the Antarctic coasts. Indirect communication with the Pacific is also maintained by numerous straits and channels between the various islands of the Malay Archipelago, the principal being the Straits of Malacca, Sunda, Lombok, and Torres. The direct communication between the Mediterranean and the Red Sea by means of the Suez Canal has been already observed.

27. Of the Arctic Ocean it will suffice to notice that—with the exception of Behring's Strait, leading into the *Pacific*, and Davis Strait, East Greenland Channel, and the wider expanse between Iceland and the Norwegian coasts leading into the *Atlantic*—it is almost entirely land-locked, the northern limits of the surrounding land following very nearly the parallel of 72° N. lat. The Antarctic Ocean is limited only in a few places by natural boundaries, its waters communicating freely with those of the South Atlantic, Indian, and Pacific Oceans.

[The most frequented and commercially important lines of communication from the *Atlantic* are—(1) By the Mediterranean, Suez Canal, and Red Sea, or (2) round the Cape of Good Hope, to India, China, &c. (3) Round Cape Horn, or through Magellan Straits into the Southern Ocean. In the *Pacific* the great lines are—(1) From San Francisco to China, &c., via the Sandwich Is. (2) From Panama to Australia. (3) From Australia to England by Cape Horn. In the *Indian Ocean* we have the direct route, (1) From China, Japan, India, &c., through the Red Sea, Suez Canal, or (2) round the Cape of Good Hope. (3) Outward route *to* Australia between 30th and 40th parallel, south latitude.]

V.

OCEANIC RIVER-SYSTEMS.

28. The foregoing articles on the distribution, relative areas and position, principal and minor divisions, of the great waters of the globe, together with their intercommunication, require a brief sketch of the principal oceanic river-systems, to complete what may be termed the general geography of the oceans. The principal general facts have been thus grouped together in the first part of the work as being absolutely necessary to further study of the physical and special geography of the oceans.

29. We have said (art. 2) that the ocean covers the more considerable depressions of the earth's outer crust, and that the land, generally speaking, is more or less elevated above the surface of the sea. Water naturally seeks to reach the lowest possible level, and thus all, or nearly all, the running waters of the globe flow directly or indirectly into the ocean; the only exceptions being a few rivers which discharge their waters into inland seas or lakes, or are lost in arid deserts, their volume of water being too limited to withstand the double action of excessive evaporation and constant infiltration through the generally permeable ground over which they flow. The ocean, then, being the great receptacle of the rivers of the globe, it follows that the natural classification of the various river-systems must correspond to the natural divisions of the sea. The land masses being contiguous to four of the five oceans, we have primarily four great oceanic river-systems,

the Arctic, Atlantic, Indian, and Pacific. Leaving the details of each system for insertion in the sections devoted to each ocean, we shall now simply make a general classification, noting only the principal rivers.

30. The universal tendency of all running waters to move towards the sea is, as we have said, due to the relief or comparative elevation of the land masses generally. What particular ocean or part of the ocean they will flow into depends likewise upon the relief of the particular portion of the land over which they flow. It being a fact of almost universal application, that the more elevated portions of the land proximate more or less to the ocean, the relief of all the land masses will, generally speaking, present the same general characteristics; the main element being, on one side, a short steep counter-slope towards that part of the ocean immediately approximating it, and a long slope on the other. The latter, of course, facilitates the formation of rivers of considerable length; the former, of shorter and more rapid streams.

31. Applying the above principles to the continental land masses, we find their most perfect and uniform illustration in the western mountain ranges of America, which follow the coast line of the Pacific Ocean from Alaska on the north, to Tierra del Fuego on the south, with remarkable regularity. The Andes in South America uniformly follow the sinuosities of the coast, while the Rocky Mountains in North America preserve the same parallelism to the coast, though at a greater and more variable distance. In the Old World the working out of the same law of position is seen in the mountain chains of southern Europe approximating generally to the Mediterranean—the Himalaya, Nanling, and other ranges of South-eastern Asia approximating to the Indian Ocean and China Sea; while even the central ranges of the Kwen-lung, Pe-ling, Thian-shan, approach nearer the Indian than the Arctic Ocean. In Africa, again, and in Australia, all the

great mountain chains are situated on or near the sea; in either case following the general trend of the coast, *e.g.* the Kong, Nieuveldt, and Drakensberg Ranges in the former, and the Australian Alps, Blue Mountains, and Liverpool Range in the latter. In our own islands it is scarcely necessary to contrast the elevated districts on the west, and the more level tracts on the east, of England. A careful examination of good physical maps will enable the student to make a complete list of cases illustrating the law of position of mountain ranges.

32. And since the relief of the various continents determines the direction in which their rivers must flow, we find that the greatest slope of the land masses are towards the Arctic and Atlantic Oceans, which therefore receive by far the larger number of the rivers of the globe. And as the shorter slope of the New World is towards the Pacific, and of the Old World towards the Pacific and Indian Oceans, it follows that these two oceans do not receive as many rivers as the Arctic and Atlantic Oceans; the average length of the principal streams, however, is nearly the same, but the drainage areas of the latter exceed those of the former. As the lengths, areas, and other particulars will be noticed further on in the third part of the work, we shall only give here the names and localities of the principal rivers in each system.

33. *The Arctic River System* comprises the great Siberian rivers—Kolyma, Indigirka, Iana, Lena, Olenek, Yenesei, and Obi, draining the Asiatic Continent north of the Altai and Aldan Mountains; the Petchora, Mezen, and Dvina, draining the northern part of European Russia; and the Great Fish, Coppermine, and Mackenzie, draining the extreme northern part of North America.

34. *The Atlantic River System* comprises a large number of rivers that do not flow into it directly, but discharge their waters into some of the minor seas belonging to it. Thus the Baltic receives the Tornea, Dal, and other Swedish rivers, and the Neva, Dvina, Vistula, and Oder, draining western Russia

and northern Germany. The Elbe, Weser, and Rhine, draining Western Germany, enter the North Sea; the Seine, Loire, and Garonne drain France, and the former falls into the English Channel, the other two into the Bay of Biscay; the Douro, Tagus, Gaudiana, and Gaudalquiver drain the Atlantic slope of the Spanish Peninsula. Of the principal British rivers, the Thames, Tweed, and Tay flow into the North Sea; the Severn into the Bristol Channel; and the Shannon into the Atlantic. The Ebro, Rhone, Po, and other rivers draining southern Europe, flow into the Mediterranean; the Danube, Dneister, and Dnieper fall into the Black Sea, and the Don into the Sea of Azov. The Mediterranean also receives the largest African river, the Nile. The Senegal, Gambia, Niger or Quorra, Congo or Livingstone River, Coanza, Orange or Gariep, and other rivers draining the western slope of Africa, flow directly into the Atlantic.

35. We have already noticed the characteristic element of the relief of both North and South America, viz., the proximity of its main mountain chains to the Pacific coast. The Andes, in South America, lie so close to the western coast as to prevent the formation of any rivers of considerable length—nearly all flowing into the Pacific from Panama to Tierra del Fuego being mere mountain torrents. The chain of the Rocky Mountains, in North America, although preserving a general parallelism to the Pacific coast, do not lie so close to the shore, and thus allow of the formation of several considerable rivers. So that the main slope of both North and South America is towards the Atlantic, which receives the drainage of the whole continent east of the Rocky Mountains and the Andes, with the exception of a portion of British North America drained by the Mackenzie, Coppermine, and a few other rivers falling into the Arctic Ocean. Of the North American rivers, the only one of importance flowing directly into the Atlantic is the St. Lawrence; the Saskatchewan, Churchill, Severn, and other rivers fall into Hudson Bay;

and the Mississippi, Rio del Norte, Colorado, &c., enter the Gulf of Mexico.

36. The South American section of the Atlantic river system comprises several rivers of considerable length and area of drainage. Of these the Amazon, rising in the Andes at a point not sixty miles from the Pacific, and draining the whole country thence to the Atlantic seaboard, is the largest river in the world. Besides the Amazon, the other principal rivers are the Magdalena, draining New Granada, and discharging its waters into the Caribbean Sea; the Orinocco, draining Venezuela; the Essequibo, Surinam and Maroni, draining Guiana; the Tocantins, Paranhyba, San Francisco, the various affluents of the Rio de la Plata, the Uruguay, Parana, Paraguay, Pilcomayo, Vermejo, Salado, the Colorado, Negro, Chupat and other smaller Patagonian streams, draining the territories east and south of the basin of the Amazon.

37. *The Pacific River System* is not so extensive as that of the Atlantic. For instance, on its eastern or American side, for the reasons already stated, it does not receive a single river approaching in size and importance to the Amazon or Mississippi. The longest is probably the Yukon, draining the Alaska Peninsula; the only other considerable rivers are the Fraser, Columbia, Colorado (Gulf of California), and the Mexican river, Santiago. The South American section of the Pacific river system does not comprise a single river worth noticing, all being mere torrents. The principal mountain chains of Eastern Asia do not approximate the coast so persistently as the Andes. Indeed, with the exception of the Aldan, Khinghan, and Manchooria coast range, the principal elevations traverse the slope to the Pacific in a generally west-to-east direction, thus allowing the flow of the drainage waters of the central Asiatic plateaux between them to the Pacific Ocean. The Amour or Sagalien, draining the southern and eastern slopes of the Altai and adjacent ranges, enters the Sea of Okhotsk. The Hwangho, Yang-tze-kiang,

Chookiang or Canton River, drain the greater part of China; while the Indo-Chinese peninsula is drained by the Maykiang or Mekong, and the Meinam, falling into the China Sea and Gulf of Siam respectively. The Australian section of the Pacific river system presents the same limited area for development as the South American,—the Australian Alps, Blue Mountains, Liverpool Range, and other northern elevations lying near and generally parallel to the coast. The Burdekin, and Mackenzie or Fitzroy, are the most considerable in length. The other numerous streams, though doubtless of great local importance, are not sufficiently large to merit special notice.

38. *The Indian River System* is naturally divided into three sections—viz., those of its limiting continents, the African on the west, the Asiatic on the north, and the Australian on the east. Of the east African rivers, the most considerable are the Zambesi and Limpopo; the Rovuma, Lufiji, Gananeh, and Shebeyli are as yet imperfectly known. The Asiatic section comprises some of the largest rivers on the globe, the principal being,—the Euphrates and Tigris, draining south-western Asia, and entering the Persian Gulf; the Indus, Nerbudda, Krishna, Godavery, Mahanuddy, Ganges, and Brahmapootra, draining India; and the Irrawady and Martaban or Salween, draining Further India. Of the Australian rivers flowing into the Indian Ocean, the Murray is the only one of considerable length. With its tributaries, the Darling, Lachlan, and Murrumbidgee, it drains nearly the whole of New South Wales and Victoria. The Mitchell, Flinders, Roper, and other unimportant streams, fall into the Gulf of Carpentaria; the Gascoigne, Murchison, Swan River, and other west Australian rivers, flow directly into the Indian Ocean.

VI.

NAVIGATION AND PROGRESS OF DISCOVERY.

39. It may, perhaps, be not unadvisable to close the generalities in the first section of this little work with a brief sketch of the progress of navigation, from the first limited efforts of the early navigators from port to port in the Mediterranean to the present time, when, with but a tiny needle for his guide, the navigator boldly crosses and recrosses the widest expanses of the ocean, undeterred by any of the doubts and fears which beset the ancient mariners on losing sight of the land. We shall again advert more particularly to this portion of the subject in the particular description of each ocean; meanwhile the main features in the history of navigation will suffice.

40. The ancients firmly believed the earth to be flat, and of a circular form, bounded on each side by an impassable ocean. The Mediterranean was the only known sea. The Greeks fondly imagined their country to be the centre of the whole world; the Danube on the north, Africa on the south, the Straits of Gibraltar on the west, and Asia Minor on the east, forming the limits in each direction. It fell to the adventurous navigators of Phœnicia and Carthage to push boldly past the Pillars of Hercules into the broad Atlantic, and thus the Canary and British Islands, and intervening tracts of Europe and Africa, became known. The military operations of Alexander widened the limit eastward as far as India. One philosopher, at least, in these early times, Aristotle, conceived the idea of the earth's rotundity, and

the consequent possibility of reaching India by sailing west. In the time of Strabo, the known world embraced the north of Africa; Europe to the Atlantic on the west, the Baltic on the north, and the Caspian on the east; Asia as far as the Ganges and Ceylon and the Persian Gulf on the south—the whole surrounded by a vast ocean. The Roman conquests greatly favoured the progress of discovery in almost every direction. Ptolemy and succeeding geographers gradually obtained knowledge of China, Siam, and other Asiatic countries; the Scandinavian "Vikings" brought Northern Europe into notice; Marco Polo travelled as far as China in 1271.

41. It will be observed that the progress of discovery thus far was mostly by land, but commercial rivalry between the great maritime nations of Europe led to the dispatch of expeditions of discovery by sea. Portuguese vessels discovered the Azores in 1439, and Cape Verde Islands in 1456; sixteen years later the Equator was crossed; and in 1486 Diaz sighted the Cape of Good Hope. The lull in further progress south was more than compensated by the greatest discovery yet made to the west. The Atlantic was crossed by Columbus, who hoped thus to reach India, and on the 12th of October, 1492, the Bahamas were sighted; and, seven years later, it was generally known that two great continents lay to the north and south of the newly-discovered chain of islands. The Cape of Good Hope was doubled in 1497; the way by sea to India was opened, and the discovery and exploration of the coasts of south-eastern Asia was rapidly accomplished—Further India, the Malay Archipelago, China, and Japan being successively visited before 1542.

42. The exploration of the northern shores of America was carried on energetically by the British—Newfoundland, Labrador, &c., being discovered by Cabot and Corteral; the Spaniards devoted themselves to Central and South America; Magellan in 1520 threaded the strait which still bears his name, and pushed boldly across the Pacific to the Philippines

and the Moluccas, returning to Europe by way of the Cape of Good Hope, being thus the first to circumnavigate the globe. Discovery and conquest went hand in hand, and thus the splendid colonial possessions of Spain gradually extended, until nearly the whole of the American continent south of Mexico owned its sway, and contributed to its wealth.

43. The exploration of the Pacific shores dates from 1513, when Balboa first saw it from the hills of Panama; Chili and California soon after resounded with the shouts of enthusiastic voyagers. The northern seas, cold and inhospitable, offered little inducement compared with the silver mines of Mexico and the gold-fields of Peru. But, though later, the frozen arctic regions were finally added to the map of the World; the English first seizing Nova Zembla, the Russians Kamtchatka and Behring's Strait, the latter being first navigated in 1722. Thence sprung up the idea of a "north-east passage" from the North Atlantic into the Pacific, round the northern shores of Europe and Asia, which the recent voyage of the *Vega* has shown to be practicable in summer. The "North-west Passage" through the Arctic Archipelago remained undiscovered until 1850, when Captain McClure succeeded in piercing the generally ice-bound channels. To the south, adventurous navigators came in sight of the island-continent of Australia, subsequently explored more minutely by the Dutch and English. The north-east coast of Asia, and the north-western shores of America, and the numerous archipelagos in the Pacific, were successively explored by Cook, La Perouse, and other famous navigators, and thus gradually the exact position and contour of the land masses became accurately known.

44. In the present century, the numerous voyages, directly scientific or purely commercial in their object, have all contributed to our geographical knowledge to such an extent that scarcely any portion of the open sea can be said to be untraversed. The probability of reaching the supposed open sea at the Pole has induced English, American, Swedish, and

Austrian navigators to imperil their lives in futile attempts to penetrate the as yet impenetrable barrier of ice which seems to surround the immediate neighbourhood of the North Pole. The African continent, of the interior of which not so long ago nothing was definitely known, has attracted many explorers; the names of Livingstone, Speke, Grant, Stanley, Cameron, and others, are well known in connection with the persistent and successful attempts to solve the problem of the physical conformation of this part of the globe. The entirely or imperfectly known tracts in Central Asia are also being gradually explored by the Russians from the north and the British from the south. Indeed, so energetic is the prosecution of both Asiatic and African exploration, that probably in less than fifty years hence both these continents will be comparatively as well known as Europe or North America.

[Fuller details of the progress of discovery will be found in the historical notes appended to each section in Part III. These notes are necessarily restricted to the history of discovery by *sea* only. Should the student desire to supplement this by a study of discovery by *land*, ample information, illustrated by an admirable series of maps, showing the progress of discovery from 1000 B.C. to the present time, will be found in Keith Johnston's last, and probably most valuable, work.*

* *Geography, Physical, Historical, and Descriptive.*—(Stanford.)

PART II.

PHYSICAL GEOGRAPHY OF THE OCEANS.

I.—Introduction.

II.—The Salts of the Sea.

III.—The Density, Colour, and Phosphorescence of the Sea.

IV.—Depth of the Ocean, and Form of Sea-Bottom.

V.—Distribution of Marine Life.

VI.—Temperature of the Ocean.

VII.—Movements of the Ocean.—waves.

VIII.—Sidereal Movements, or Tides.

IX.—Proper Movements, or Currents.

X.—Influence of the Sea on the Distribution of Climate.

XI.—Action of the Sea on the Earth's Crust.

II.

PHYSICAL GEOGRAPHY OF THE OCEANS.

I.

INTRODUCTION.

45. The cohesion of particles of water being limited, they are free to arrange themselves in obedience to the slightest impulse. This, in conjunction with its all but incompressibility, is the cause of what we may call the sensitiveness of water to disturbances; the most common forms of which are wind-waves. It being one of the characteristics of water that depression at any one point is always and necessarily accompanied by an equal elevation at another point, it follows that the impact of a moving column of air on the surface of the water causes a greater or less degree of depression at the point of impact, and a corresponding elevation immediately beyond that point; and thus waves, the simplest of all the disturbances to which the ocean is subject, are produced. But the disturbance in this case is temporary; the withdrawal or suspension of the disturbing element is immediately followed by the subsidence of the elevated part of the water, and the resumption by the depressed part of its normal level. And so, although it cannot perhaps be said that every part of the ocean's surface is always uniformly level, owing to the frequent disturbances by winds, tides, &c., yet, as these are, in fact, local and temporary, the surface of the ocean is, generally speaking, level, corre-

sponding with the mean level of the earth as part of its circumference. The *sea-level*, as it is termed, then, is the general elevation of the great mass of the ocean, and its uniformity in widely different localities is such that the distance between the surface of the water and the exact centre of the earth (allowing of course for the excess in the diameter of equatorial regions) must be equal. The sea-level, being thus universally uniform, is adopted as the standard of all measurements of height on land or depth at sea. The earth being a sphere, the surface of the ocean is also curved, and there being nothing to obstruct the view as on land, this curvature is more apparent at sea than on land, as is strikingly shown by the disappearance, first of the hulls, and last, of the topmasts of vessels leaving the land.

46. Besides this *curvature of the sea* as a whole, and its assumption of a generally uniform level, we have to consider other physical peculiarities of the waters of the ocean. One distinctive feature of sea-water is its *saltness*, a property both universal and uniform. Closely connected with its salinity are the *density* and *colour* of sea water. Other points in the physical geography of the sea, that command our attention, are its *temperature*, *depth*, and the various movements to which it is subject—*waves*, *tides*, and *currents*.

II.

THE SALTS OF THE SEA.

Composition of Sea Water.

47. Water, chemically considered, is composed of two gases—hydrogen and oxygen, combined in the proportion of eight parts of oxygen to one of hydrogen *by weight*, or of two parts of hydrogen and one of oxygen *by volume;* or, more accurately, 100 parts by weight of water consists of 88.89 parts of oxygen and 11.11 parts of hydrogen. This, of course, is the chemical composition of perfectly pure water. But water is never naturally found absolutely pure, always containing greater or less quantities of certain substances, chemically dissolved, or mechanically suspended, in it. Sea water mainly differs from the so-called fresh water in being more or less salt. This *saltness* of sea water is due to the presence of certain saline matters held in chemical solution in it—the amount of solid matters dissolved in, and separable from, sea water, ranging from an average of 3.5 to an average of, in extreme cases, 4.5 per cent. The following is the mean of several analyses of sea water:—

Chemically pure water, consisting of oxygen and hydrogen only	96·470
Chloride of sodium (common salt)	2·700
Other saline ingredients	·805
Loss (iodides, silica, &c.)	·025
	100·000

As a fair average, then, we may say that 100 lbs. of sea water consists of 96½ lbs. of water and 3½ lbs. of solid matters in solution. And when we consider the vast extent of the ocean, the total quantity of solid matters dissolved in its waters must be enormous. In fact, it has been computed that it would cover an area of 7,000,000 square miles to a depth of fully one mile, and this estimate is most probably below the actual amount.

48. In nearly every part of the open ocean, the proportion of saline ingredients in solution is, generally speaking, the same. This remarkable uniformity in composition is no doubt the result of the continuous movements and consequent co-mingling of the waters of the ocean. There is certainly a slight difference in various parts; but even this is attributable to local or temporary causes, and scarcely affects the general statement that the sea, as regards saltness, is everywhere the same. The main causes of the slight differences are the varying degree of evaporation, and the supply of fresh water by rains and rivers. For instance, the seas of the Southern Hemisphere are slightly salter than those of the Northern Hemisphere—a result, evidently, of excessive evaporation in the former, and excessive precipitation in the latter. The areas of *maximum saltness*[1] are in the North and South Atlantic, between 20° and 40° W. long. on either side of the Tropics of Cancer and Capricorn respectively. Towards the poles there is a gradual but very slight diminution in the degree of salinity.

49. On the other hand, the difference is most marked in certain limited or peculiarly situated areas, whose waters are respectively fresher or salter than those of the contiguous open sea. Thus inland seas subject to minimum evaporation are generally fresher than those subject to maximum evaporation, although the supply of fresh river water to the latter may actually exceed that to the former; for instance, the Baltic is considerably fresher than the Caspian, although the latter

[1] See foot-note, page 36.

receives a vastly greater quantity of fresh water—the Volga alone being estimated to discharge as much fresh water as the whole of the rivers of Southern Europe taken together. But while evaporation is languid in the Baltic, it is exceedingly active in the Caspian.

50. The saltness is still further increased if an inland sea be subject to active evaporation and yet receive no considerable quantity of fresh river water. A notable instance of this is the Red Sea.[1] Closed in on all sides by arid deserts, it is subject to excessive evaporation—so much so, indeed, that were the Straits of Bab-el-mandeb permanently closed, and the compensating inflow from the Indian Ocean stopped, its level would be lowered about eight feet annually, and in a few years at most its bed would be but a vast "Wady," nearly, if not entirely, destitute of water. The inflow, as we have said, from the Indian Ocean prevents the lowering of the level, by supplying an amount equivalent to that evaporated. No rivers enter this arm of the sea, and the whole region is nearly rainless, so that in the Red Sea we have maximum evaporation, and minimum freshwater supply, resulting in a degree of salinity exceeding that of the open ocean. In the Mediterranean we have an example, again, of active evaporation, but combined with a considerable supply of fresh water by the Nile, Rhone, and other large rivers; still the amount evaporated is in excess of the fresh water supply, and consequently the waters of the great inland sea are salter than those of the Atlantic. Instances of excessive evaporation and limited supply of fresh water, together with total absence of compensating supply by inflow from the adjoining ocean, are the Dead Sea, and the Sea of Aral, both, especially the former, excessively salt.

51. It will be readily seen that the saltness of the sea will be, generally speaking, not only more uniform, but also somewhat greater at certain depths than at the surface. For the surface waters of the sea are nearly everywhere more or less

[1] So called from the coral reefs which abound in it.

subject to admixture with large quantities of fresh water from rivers, rainfall, or melting icebergs. And as the fresh water thus obtained is specifically lighter than the salt water on which it falls, or over which it flows, it will float on the surface for some time. This comparative freshness of the surface water is, of course, greater in certain localities and under certain conditions, as at the mouths of large rivers, or immediately after excessive rainfall, or, in the polar seas, after extensive liquefaction of enormous icebergs. In fact, water fit for use has been often "skimmed" from the surface of the sea several miles out; and it is a proved fact that the fresher waters of the Amazon may be perceived even at a distance of two hundred miles out in the open sea. The regions of *minimum saltness* are[1]—the Gulf of Guinea, North Sea, a narrow belt along the American coast from Newfoundland to Florida, in the Atlantic; about 5° north and south of the Equator in the Indian Ocean; about 10° north and south of the Tropic of Cancer in the Pacific; and south of lat. 40° S. in the Southern Ocean.

52. Besides the saline matters chemically dissolved in the waters of the ocean, other ingredients are temporarily mechanically suspended in its waters—sand, mud, and other *debris* being nearly always present, especially near the coast, but never in any very considerable quantities. These substances are brought down by rivers, or washed off the coast by wind-waves and tides; and although the finer particles are probably transported to great distances, the greater portion are deposited on the bottom of the sea in the immediate neighbourhood of the coast. This transport and deposition of sand and other *debris* form the shoals and banks so dangerous to navigation. In most cases there is an incessant change in the position or extent of these shallows, rendering frequent surveys absolutely necessary.

[1] As given in Mr. Buchanan's chart, showing the "Distribution of Saltness in the Ocean."

The Salts of the Sea, whence derived, and how their uniform proportion is maintained.

53. Generally speaking, the waters of the ocean may be said to be universally uniform as regards the proportions of saline matters held in solution, and we have no proof that this remarkable and universal uniformity of composition has ever undergone any alteration. On the contrary, we have reason to believe that the waters of the ocean, even in the earliest geological ages, were as salt as they are now, for the fossil fauna of the earth comprises numerous species that could not have existed in fresh water, or indeed in any water perceptibly different in composition to that of the present sea-water. Bearing in mind the striking fact that the degree of saltness is pretty nearly the same throughout the whole extent of the ocean, and that the proportions of ingredients most probably has never changed, we naturally desire some solution to the queries—(1) Whence did the waters of the ocean originally derive their salts? and supposing their origin to be satisfactorily accounted for, (2) How can we explain the remarkable uniformity in the composition of sea-water throughout the whole extent of the ocean? and further, (3) What are the results of the saltness of the ocean?

54. In the first place, *whence did the waters of the ocean originally derive their salts?* This problem is from its very nature incapable of other than an indirect solution and demonstration. Several theories, all more or less plausible, have been advanced with the object of satisfactorily accounting for the presence of salts in the waters of the sea. The generally received opinion is that they were originally derived from the "washings of the rains and the rivers." The condensed moisture in the air falls on the land in the shape of *rain* and *snow*, moistening all the exposed surfaces, and dissolving every substance which it can hold in solution, and percolating

through the softer, and passing over the harder surface strata, gradually collecting and forming small *streams*, a number of which uniting their waters form a *river*, which finally discharges the collected waters of its *basin*, laden with the "spoils of the land," into the sea. Of the many substances dissolved from the time it reached the ground as rain, to its final reception in one mighty flood by the sea, the more readily dissolved substances will, of course, be carried down in greater quantities than the others. And we find that nearly all the saline matters found in the waters of the ocean are always present in the so-called fresh water of all rivers, though, of course, in a scarcely appreciable quantity. But though comparatively small in any given portion of even the larger rivers, yet the total quantity of saline substances carried into the ocean by all the rivers of the globe must be enormous; and in this way alone, supposing the ocean to have been fresh in former periods, its present saltness may be easily accounted for—the salts gradually accumulating and being evenly diffused through the mass of the ocean by the constant circulation of its waters.

[Mr. J. Y. Buchanan, chemist and physicist in the *Challenger Expedition*, is of opinion[1] that "the source of the salts existing in sea-water is rock substance which has been disintegrated and decomposed by atmospheric influences. The soluble components or products washed out by the rain, and collected in the streams and rivers, are eventually poured into the sea. Here the water is subjected to the action of the sun and winds, which causes it to evaporate, leaving the salts behind. A great quantity of the vapour so formed is carried inland, and condensed on the mountains, washing out the rock and taking up a fresh charge of solid matter, which it brings down into the sea, which is thus the great receptacle of degraded land."]

[1] *Journal of the Royal Geographical Society*, vol. xlvii., p. 73.

55. It may be objected to this theory that the waters of the ocean must in course of time get perceptibly salter, for not a particle of the saline substances brought down by rivers is ever removed by evaporation. Fresh water alone being capable of conversion into water, the salts are left behind, and must therefore accumulate. But repeated geological researches show most conclusively that there has been no such change as this would necessarily involve, and that, as regards its component parts, the ocean must long since have arrived at a state of equilibrium; the continual supplies of saline matters being equalized, or nearly so, by the incessant demands of the myriad forms of marine organisms with which the ocean teems; any amount still in excess being most probably chemically involved in the formation of new strata at the bottom of the sea. Maury, the great physical geographer of the sea, while admitting the fact that "rains and rivers do dissolve salts of various kinds from the rocks and soil, and empty them into the sea," still dissents from the theory that the sea *originally derived* its salts in this manner. He contends that "if the sea derived its salts originally from the rivers, the geological records of the past would show that river beds were scored out of the crust of our planet before the sea had deposited any of its fossil shells and infusorial remains upon it." He states further, that if this be true, there must have been a time when there either was no sea, or that it was fresh, and consequently without "shells or animals of the silicious or calcareous kinds." But both Palæontological records and the Mosaic account of the Creation prove the contrary; and, on the double evidence of geology and inspiration, he believes that the "fossil shell and the remains of marine organisms inform us, that when the foundations of our mountains were laid with granite, and immediately succeeding that remote period when the primary formations were completed, the sea was, as it is now, salt."[1]

[1] *The Physical Geography of the Sea.*

56. The objection that may be made as to the absolute quantity of solid matters in solution in the waters of the sea is not so relevant, and may be met with the plea that although the amount of saline matters *annually* consigned to the sea by the rivers of the globe may be comparatively insignificant, yet, as we cannot tell how many ages have elapsed since the process began, the amount carried down altogether would suffice to account for the present saltness. Even if we consider the total quantity—taking the proportion of salts to be 3.5 per cent.—estimated to be sufficient to cover an area of 7,000,000 square miles to a depth of one mile, as rather over than under the actual quantity, still it may be probable that, in the course of time, the rivers, which furrow almost every part of the surface of the land, aided by the movements of the sea itself (more especially the incessant action of its waves on thousands of miles of coast, perpetually disintegrating the exposed strata along the shore-line), may have gradually accumulated the amount of saline ingredients we now find dissolved throughout the mass of the ocean.

57. Another theory, evidently an outgrowth of the preceding one, supposes that the waters of the ocean were originally fresh, but acquired their present saltness by dissolving the saline materials in the exposed strata of its basin—the uniformity of proportion being simply the result of the admixture and mingling of its waters.

58. But the most probable solution of this problem is, that the waters of the ocean "have always been salt, ever since they were condensed out of the original atmosphere of gas and vapour, and carried down the saline vapours which were no doubt at first diffused abundantly through that atmosphere."[1] This theory harmonizes with the consistent records of palæontology, which certainly do not support the idea that the ocean was originally fresh, and consequently devoid of nearly all, if not all, its characteristic organisms. We cannot

[1] Geikie,—*Lessons in Physical Geography* (Macmillan).

tell why so many marine organisms have died out; but if it was because the sea got gradually salter, why did not the coral insect, whose records probably point to a date anterior to several of them, perish and become extinct likewise? As Maury aptly remarks, the various marine animals which have become extinct, died out because they "ceased to find the climates of the sea, not the proportion of its salts, suited to their well-being."

Results of the Saltness of the Sea.

59. It is a well-known fact that, under similar conditions, evaporation is much more rapid from fresh than from salt water. The actual difference has been experimentally proved to be about 0.54 per cent., so that it is highly probable that the saltness of the sea was "mainly intended to regulate evaporation." This "regulation of evaporation" is a most comprehensive term, and one that affects the physical "life of the globe" in almost every direction. The amount of moisture in the air, and therefore the rainfall, the water-supply, and dependent vegetable and animal life—in fact, almost all climatical phenomena, are either directly or indirectly affected by evaporation. As we shall again point out, the grand system of oceanic circulation is, most probably, primarily due to differences of density, consequent on excessive evaporation in certain localities. Had the sea, therefore, been fresh, evaporation would be much more active; the rainfall would consequently be greater—countries now moderately moist would be almost constantly deluged with heavy rains and copious dews—in fact, the whole climatic conditions[1] of every

[1] "In fact, the saltness of the water at any place becomes ultimately a function of the *relative dryness* of the atmosphere in the locality; that is, the further the air is removed from saturation with moisture, the greater will be its evaporating power, and consequently the more marked will be its effect in the resultant saltness of the water exposed to its action. The regions, therefore, of high specific gravity of ocean water will coincide with those of high atmospheric dryness, and those of low specific gravity of the water with those of low atmospheric dryness. Thus, in the trade-wind regions we find the highest specific

part of the earth would be changed, beneficially perhaps to some districts, but undoubtedly deleterious to the greater part of the civilized world.

60. But, besides being less vaporizable, salt water does not freeze so readily as fresh water. Fresh water freezes at 32° F., while salt water is not converted into ice until its temperature is reduced to 28½° F., or even lower. The result of this important difference is twofold—a larger portion of the sea is permanently open and accessible; and, bulk for bulk, the sea "stores," as it were, a greater degree of heat than the land —to be given out again when the latter is covered with the snows and ice of winter. By its capability of retaining permanently a greater degree of heat than the land, without a correspondingly high elevation of temperature, it moderates the heat of summer; and, by its insensitiveness, if we may say so, to cold, it parts with its surplus heat to the land in winter without its temperature being reduced in the same degree. Both these results, less evaporation and slower congelation, are undoubtedly due to the presence of the saline matters in solution in the waters of the ocean.

---

gravity of the water associated with the greatest dryness of the air, and in the region of the equatorial calms we have a low specific gravity of the water associated with heavy rains and a damp atmosphere "—*On the Distribution of Salt in the Ocean*, a paper read by Mr. Buchanan before the Royal Geographical Society, March 12th, 1877.

III.

DENSITY, COLOUR, AND PHOSPHORESCENCE OF THE SEA.

Density of Sea-Water.

61. Since sea water contains from 3.5 to 4.5 per cent. of solid matters in solution, it is therefore, bulk for bulk, heavier than fresh water. For instance, a cubic foot of fresh water weighs 1,000 oz., but the same quantity of sea water weighs 1,026 oz. Carefully conducted experiments have been repeatedly made to determine accurately the specific gravity or relative weight of sea water, absolutely fresh water at 62° F. being taken as the standard. The mean of several results gives 1.0275 as the specific gravity of sea water, fresh water being taken as 1. But, as we have said before, the degree of salinity is not exactly the same in every part of the ocean, being greatest in areas subject to active evaporation, and least in those with minimum evaporation, and yet receiving large supplies of fresh water; and the salter the water is, the greater will be its specific gravity, but the difference in various localities is very slight. Thus the specific gravity of the waters of the North Atlantic is said to be 1.0266, and that of the South Atlantic, 1.0267, showing a difference of .0001 only; that of the North Pacific, 1.0254, of the South Pacific, 1.0265, a difference of only .0011; that of the Baltic, 1.0086, of the Red Sea, 1.0286, a difference of .02; the Mediterranean, 1.0289; and the Indian Ocean, 1.0263. So that the average difference in the specific gravities of the Atlantic and Pacific Oceans is .0007, or, in

other words, the Atlantic is slightly salter than the Pacific. On the other hand, the difference between the Baltic and the Mediterranean is more marked, being .0203, that is, the water of the Mediterranean is one-fiftieth part salter than those of the Baltic; or, in other words, 100 lbs. of Mediterranean water would contain .08 lbs. more saline matters than the same quantity of Baltic water. The difference in this case exceeds the general variation, and a proportion of only 1.28 oz. per 100 lbs. might be looked upon as practically too small to be noticed, were it not that the least difference is the immediate cause of an incessant interchange of the particles of water of different densities; and thus, as we shall again point out more fully, the vertical, and probably in a large measure the horizontal, circulation of the waters of the ocean, immediately depend on an infinitesimal difference in the density, whether arising from a varying degree of saltness or temperature, of different parts of the ocean.

62. Fresh water is specifically lighter than salt water, and as enormous quantities of fresh water are constantly poured into the sea by rivers, or precipitated on its surface as rain, the surface water of the sea will be found to be generally fresher than that at great depths, inasmuch as the lighter fresh water will "float" on the surface for a considerable time before it is thoroughly mixed with the underlying salt water. Generally speaking, then, the specific gravity of sea water at the surface will be somewhat less than that at great depths. But besides this, water is slightly compressible, being at a depth of 1000 feet compressed $\frac{1}{30}$ of its bulk. The pressure of the superincumbent water at a depth of one mile has been calculated at 2000 lbs. per square inch, and this pressure increases at a uniform rate to the lowest depths. But, strangely enough, the density does not increase uniformly with the depth, and in some localities the surface water is actually denser than that at the bottom. Thus the specific gravity of the surface water at a point in the north Atlantic, 54° 28′ N. lat., and 11° 44′ W.

long., was found to be 1.028; while at the bottom, at a depth of 8550 feet, it was only 1.0269—the surface water showing an excess in density of .0011.[1] The greater density in this case was most probably due to temporary causes, such as excessive evaporation and limited precipitation at the time of the observation; but in certain areas the same causes are so constant in their operation, that the surface water is permanently denser than that at the bottom.

63. The greatest density of fresh water is at 39.2° F.; further reduction in its temperature causes it to expand until it reaches the freezing point, 32° F. But salt water does not expand until it reaches the freezing point, so that its point of greatest density nearly corresponds to its freezing point. This point is several degrees lower than that of fresh water, being $28\frac{1}{4}$° F., or even lower, under certain conditions. And since fresh water only is converted into ice, the freezing of the surface waters of the polar seas is always accompanied by an increase in the saltness of the water immediately beneath the icy crust: an effect exactly the same, but produced by very different means, as that of excessive evaporation. So that excessive cold as well as excessive heat causes an increase of the salinity of the surface-water—the former by withdrawing the fresh water in the form of ice, the latter removing the fresh water in the shape of vapour. In both cases the salts, originally dissolved in the displaced portion of the water, is left behind, and the denser surface water gradually sinks, and is replaced by lighter water from below, which is again subjected to the same process. This difference in the density of surface and deep water originates and maintains a constant "vertical circulation" of the waters of the ocean. But, as we shall explain further on, although a difference of density alone might be a sufficient cause to produce a vertical circulation at any one point, the original movements of the particles of water consequent on

[1] Sir Wyville Thomson.

a difference in density, due to the saltness of the water, are affected by the constantly varying temperature from the equator to the poles, and from the surface to the bottom.

Colour and Phosphorescence of the Sea.

64. The natural *colour* of perfectly pure water is most probably blue, but in small quantities the bluish tint cannot be perceived, and the water appears absolutely colourless. The colour of the sea varies from a greenish tint in shallow water, to a rich indigo blue in the open ocean, the depth or intensity of the colour increasing with the depth of the water. The greenish colour of shallow water is probably an effect produced by the reflection of the generally yellow colour of the sandy bottom through the natural blue tint of the water. The degree of saltness as well as the depth of the water seems to affect the richness or depth of the colour. Thus the waters of the trade-wind region, having a maximum degree of saltness, are dark blue, while the comparatively fresher and northern seas are light green. The Mediterranean generally appears of a deep azure blue, and the Gulf Stream can be readily distinguished by the deep indigo blue of its waters.

65. Besides these variations of colour in the open sea, due to varying depth and saltness, certain areas have peculiar colours due to local causes, *e.g.*, the Yellow Sea off China, Vermilion Sea (Californian Gulf), Sargasso Sea in mid-Atlantic, Red Sea, &c. The Yellow Sea is so called from the tint given to its waters by the vast amount of mud brought down by large rivers entering it. The Red Sea is a misnomer, the general colour of the channel being deep blue, the reddish tint being observable only along its coralline shores. Occasionally a reddish tint has been observed in the south Atlantic, off the mouth of the La Plata, as well as in certain parts of the Pacific. Not unfrequently the waters of the Gulf of Guinea are of a whitish colour; while in the northern seas, off Greenland, alternate streaks of green and blue have been observed.

The streaked appearance is probably due to streams of fresher surface water, derived from melting icebergs. The peculiar colours of the other areas mentioned are most probably due to the presence of vast numbers of minute marine organisms, both animal and vegetable.

66. The *phosphorescence* or *luminosity* of the sea is one of the most striking and beautiful of all its numerous phenomena. Although varying with the degree of light, state of the weather, and time of the year, it is probably observable in every part of the ocean. Mr. Skertchley, of Her Majesty's Geological Survey, thus describes[1] this truly beautiful phenomenon :— "We have seen it fitfully gleaming over the sleeping waters, and again gilding with burning light every wave and ripple within sight, sometimes so pale as to seem spectral in its whiteness, sometimes glowing in a ship's wake so powerfully that books may be read by its light. . . . Great globes of fire well up from beneath the ship's keel, or irregular patches, constantly changing in outline, float around. Every now and then a flash of fire is propagated across the surface, and all remains dark until illuminated by another similar display."

67. This luminous appearance, generally of a pale greenish colour, is much more perceptible under certain conditions—as on a dark night, when the still, calm water is disturbed by a passing vessel or boat; the sharp bow of the ship seems, as it were, to strike fire from the formerly dark glassy surface of the water, and the oars seem to dip into a halo of light. These beautiful effects are due to the presence near the surface of vast numbers of various minute luminous animals, and probably also to floating particles of decaying animal matter. The phosphorescent appearance of decaying fish by night is a well known fact, and may afford a partial explanation of this phenomenon, which is, however, generally due to living organisms, and not to decaying matter.

---

[1] *Physical Geography* (Murby).

IV.

DEPTH OF THE OCEAN, AND FORM OF SEA-BOTTOM.

Depth of the Ocean—Deep Sea Soundings.

68. Before giving the main results of the more recent researches as to the depth of the ocean, it may perhaps be advisable to present the student with a few particulars relative to the art of "deep-sea sounding," which has only recently been so perfected as to furnish us with accurate and reliable results.

69. At first sight, "sounding" seems to be one of the simplest operations possible, for what could be more easy than to ascertain the depth of the water at any locality, by simply letting down a line with a weight at one end, and then noting the actual length of line run out, which would, of course, be the actual depth at that point. In still, shallow water, the depth may be pretty accurately measured in this way, but when tried in water of considerable depth, the plan will be found to fail, as it gives greatly exaggerated results. In the first place, in "sounding" by line and weight, it was taken for granted that when the weight reached the bottom, the line would cease to run out; or, at any rate, that the observer would be able to tell, by a so-called "shock," when the weight touched the bottom. But repeated experiments proved the fallacy of both these suppositions. It was found impossible to tell exactly when the weight touched the bottom, for in many cases *the line would never cease to run out*, and the

"shock" was purely hypothetical—it being, indeed, a physical impossibility for a shock, caused by the weight falling on the bottom, to be communicated through thousands of fathoms of line to the surface. Reports of enormous depths in the open ocean were made by the early explorers; lengths of 40,000 and 50,000 feet were run out without reaching the "bottom." The subject now began to excite greater interest, and a determination to solve the matter satisfactorily,—the pioneers of deep sea-sounding being the officers of the United States Navy, acting under the direction of Captain Maury.

70. The immense length of line reported to be run out was often in itself a ground for suspicion, but the frequent affix of "no bottom" deepened the mistrust of results thus obtained. The attention of scientists was therefore directed to the root of the matter—it being evident that the errors were due to the *method* of sounding. Various projects were put forth to obviate the known obstacles which had, as yet, rendered accurate and reliable "sounding" in the open ocean impossible. The uncertain elements in "sounding," as then practised, were three-fold:—(1.) Unless in water of no considerable depth, it was doubtful whether the weight had touched the bottom or not,—the line in many cases never ceasing to run out. (2.) Supposing the weight had reached the bottom, and was stationary, it was questionable whether the line had not been deflected from its vertical position by under-currents, and if so, what was the amount of such deflection, or when did the line begin to deflect? (3.) Taking it for granted that the weight had touched the bottom, and that the line was tense throughout, it was uncertain whether the vessel from which the "soundings" were taken had not shifted its position during the operation.

71. In the first place, the uncertainty as to whether the weight had touched the bottom or not was soon solved. When deep-sea soundings first attracted general attention, some asserted that the weight could never reach the bottom, at

least in the deeper parts of the ocean, for it would be buoyed up, as it were, by the dense water at great depths. The absurdity of this opinion is evident, if we reflect that, water being all but incompressible, it would require a depth of not less than 93 miles to double its density at the surface. But the specific gravity of lead is about eleven times greater than that of water. Taking it for granted, then, that a depth of 93 miles were attained, the lead would still be five times as heavy as the water at the bottom, and, consequently, could not possibly be buoyed up even at that depth. But there are no such depths in the ocean, the deepest part probably not exceeding six miles: so that in most cases where "no bottom" was reported, the weight certainly had reached and rested on the bottom—the continued running out of the line being due to its deflection by under-currents, and not to its indefinite dragging down by the weight.

72. Supposing the weight to have reached the bottom, and remained stationary, was it not probable that the line had been deflected from its vertical position by under-currents, with the result of greatly exaggerating the depth? The immense lengths of line formerly reported to be run out confirmed what had been already guessed, viz., that in the deeper parts of the ocean the line does not cease to run out. And, as we have proved in the preceding article, the weight *must have touched the bottom*, probably at less than half the depth indicated by the length of line out. It must therefore have been deflected by under-currents.

73. The point to be determined, then, was—when did the weight touch the bottom? To solve this apparently difficult point repeated experiments were made, and eventually the "law of descent" was discovered. It was found that the line did not run out at a uniform rate, but sank more slowly as the depth increased, and that the moment the weight touched the bottom, under-currents commenced to deflect the line at a *uniform* rate. So that, by carefully noticing the time when

the line ceased to run out at a decreasing rate, and commenced running out regularly at a uniform rate, the time when the weight touched the bottom was easily ascertained, and the length of line run out thus far was evidently the actual depth at that point.

74. As regards the shifting of the station of observation during the "sounding," this was in a great measure obviated by sounding from a boat in still water; boats being found to be less liable to "shift" than large vessels. Of course this difficulty was experienced only in the open ocean, in the absence of any fixed objects whose bearings could be taken.

75. Concurrently with the desire for accurate information as to the depth of the sea, grew up the wish to know something of the nature of the floor of the ocean. The "sinkers" used in deep-sea sounding were weights of lead or iron, necessarily heavy, in order to drag down the line to the bottom, but, once there, they could not be lifted up again, so that it appeared hopeless to think of obtaining any specimens from the bottom. One of Capt. Maury's coadjutors, Lieutenant Brooke, of the United States Navy, contrived a simple but most effective apparatus, by which the weight on touching the bottom was detached, leaving a light tube only to be drawn up. At the lower end of this tube a little tallow, or the barrel of a common quill, was attached, and to this specimens of the bottom adhered, and were thus brought up for examination. The instruments used more recently on board the *Challenger* and other vessels were more finished and complicated, but the principle is the same—*the disengagement of the weight from the line on touching the bottom.* This also obviates the necessity of elaborate timing in order to determine the rate of descent, as the disengagement of the weight the moment it strikes the bottom relaxes the extreme tension of the line, which is then perfectly free.

76. But probably the most ingenious and perfect sounding apparatus yet invented, is that of Sir W. Thomson, which is

founded on the fact that the pressure of the water increases with the depth in a definite ratio, so that, given the exact pressure, the actual depth is only a matter of calculation. This apparatus is thus described by Mr. Sewill, of Liverpool :— "Sir William Thomson's Improved Sounding Machine is designed for the purpose of *ascertaining, accurately and quickly, the depth of water under a ship, without stopping or even reducing her speed.* The apparatus consists of a light wheel, on which is coiled about 300 fathoms of pianoforte steel wire. The stand to which the supports of the wheel are attached is fixed to the taffrail, at the stern of the vessel, so that the sinker can be left hanging ready for a cast. A cord wound round a groove in the circumference of the drum, is so arranged as to form a self-acting brake, which, when the sinker is hanging, offers enough of resistance to prevent it from running down, but when it is being hauled in, offers very little resistance to the turning of the wheel. When the order is given to take a sounding, the brake is released by the hand, so as to leave a force of about 7 lbs. pulling on the rope, by which a resistance of 5 lbs. is opposed to the wire while it is running out. Thus, when the sinker reaches the bottom, the wheel suddenly stops. The brake is then applied to prevent it from running on again. The sinker is a long iron weight of 22 lbs., with a hollow at the bottom to receive the usual arming of tallow, etc., to bring up a specimen of the bottom. It is attached to the end of the wire by means of a rope 6 or 8 feet long. A brass tube a little more than two feet long is lashed to the rope connecting the sinker with the wire. A glass tube, two feet long, coated inside with chromate of silver, and closed at one end and open at the other, is placed with its open end down, in the brass tube. As the sinker descends, the increased pressure drives the sea water up the glass tube, which, combining with the chromate of silver, makes a white mark. The height of the white mark registers the height to which the liquor has been forced up the tube. A scale, gra-

duated to fathoms, shows at once the depth to which the glass tube has been. This method of taking soundings depends on the increased pressure as the tube descends, but is independent of the amount of line out, so that the vessel does not require to be stopped to take a sounding. The advantages of wire over rope of the same strength, are the smallness of area and smoothness of surface, on account of which it experiences very little resistance when pulled rapidly through water. This allows the sinker to descend very quickly, and to be hauled on board again with great ease, so that two men working the machine can take soundings in 100 fathoms every few minutes, from a ship running at any speed up to 16 or 17 knots."

Depth of the Ocean.—Theory of Waves.

77. The depth of various parts of the ocean have also been approximately determined by observations on waves, and the results, thus obtained, agree in a very remarkable manner with the latest reliable "soundings." The Astronomer-Royal, Sir G. Airy, first propounded the theory that a definite relation exists between the breadth and velocity of a wave, and the depth of the water over which it travels. The results of his researches are embodied in the three laws known as the "Theory of Waves," briefly stated as follows:—(1) Waves of any breadth may be formed in water of any depth. (2) A wave of a given breadth cannot attain more than a certain velocity. (3) When the depth is less than the breadth, the motion increases nearly up to a certain velocity.

78. In two practical applications of the "Theory of Waves," to determine the depth of the Atlantic and Pacific Oceans, the tidal wave was selected in the former, and the great earthquake wave of 1854 in the latter. Herschel thus estimated the depth of the Atlantic at 22,157 feet, a number rather in excess of that given by the *Challenger* expedition, viz., 2500 fathoms, or 15,000 feet. The average depth of the Pacific was

found to be 14,190 feet, which closely approximates that given by the *Challenger*, viz., 2,400 fathoms, or 14,400 feet.

Depth of the Ocean.—General Results.

79. As the details of the depth of particular parts of the ocean will be included in the special geography of each ocean, it will suffice here to summarize the principal results of recent observations as to the depth of the ocean. The formerly general notions of enormous depths—40,000 to 50,000 feet—have been entirely dispelled. Actual measurements prove that a very large proportion of the ocean is not more than 2,000 or 3,000 feet deep, and yet four miles is frequently given as the mean depth of the sea; if so, extensive portions must be eight or ten miles deep. But it is most improbable that there are depths of more than six miles. The *Challenger* expedition of 1872-6 ascertained the depth at 150 stations in the Atlantic, and at 100 in the Pacific, and the general results show that the average depths of the ocean does not exceed 2,000 fathoms; while the greatest depth recorded, found in the Pacific, north of New Guinea, was only 4,575 fathoms, or 27,450 feet, or nearly 5¼ miles. In the Indian Ocean, the greatest depth found was 2,254 fathoms, or 13,524 feet.

80. Both the Arctic and Antarctic Oceans appear to be much shallower than any of the other three oceans. The depth in the Arctic Ocean, at a point 400 miles from the pole, was found to be only 72 fathoms, or 432 feet, while the greatest depth yet found within the Antarctic Circle was 1,975 fathoms, or 11,850 feet. The supposition that the depths of the sea generally correspond to the heights of the land is thus verified; not that there is any necessary connection between the two, for striking disparity would be expected from the great difference in area of the sea and the land. As it is, however, the greatest known depths of the ocean correspond very nearly to the highest known elevation on the land.

Pressure and Weight of the Ocean.

81. Another point closely connected with the depth of the sea is that of its *pressure*, or, in other words, the actual weight of the mass of water at various depths from the surface to the bottom. Knowing from common observation the weight of even small masses of water, one would naturally look upon the weight of the vast mass of the ocean as incalculable. But scientific researches and discoveries enable us in the present day to solve problems far more difficult and incredible than the determination of the pressure or weight of the mass of the sea. Of course, in calculating the mass or weight of all the waters of the ocean, we are obliged to work on more or less general and indefinite data. For instance, it is virtually impossible to determine the *exact* mean depth of the whole ocean. The irregularities of the bottom are such as to preclude the thought of this being done, and even the superficial extent of the ocean can only be roughly estimated; so that in all these and similar calculations a rather wide margin must be left for probable errors. Still the general estimates thus obtained are practically all that are required. The weight or mass of the ocean, in round numbers, may be easily determined. Taking the entire area of the sea at 45,500,000 square miles, and the average depth at 2,000 fathoms, or 2¼ miles, the *mass* of the ocean will be 102,375,000 cubic miles. Now, if we take 65 lbs. as the weight of a cubic foot of sea-water, the weight of a cubic mile multiplied by 102,375,000 will be the total *weight* of the ocean.

82. Again, the weight of a column of water of a given depth can be measured in the same way. For if 65 lbs. be the weight of a cubic foot of sea-water, the weight of 1,000 cubic feet will be 65,000 lbs. In other words, the pressure on a surface one foot square, at a depth of 1,000 feet, will be 65,000 lbs., or about 450 lbs. on the square inch. At a depth of 10,000 feet, the pressure will be 650,000 lbs. per square foot, or about 4,500 lbs. on the square inch; while at 20,000 feet,

the weight of the superincumbent mass of water will be equal to a pressure of 9,000 lbs. on the square inch, or a little more than 4 tons; or, as Sir Wyville Thomson puts it—at a depth of 2,000 fathoms, or 12,000 feet, a man would bear a weight equal to twenty locomotive engines, each with a long train loaded with pig-iron.

83. It is usual, also, to indicate the pressure of the water at various depths as so many atmospheres, that is, so many times the weight of the air at sea-level. Thus the pressure at a depth of one mile is equivalent to 160 atmospheres, and at 4,000 fathoms, or $4\frac{1}{2}$ miles, it amounts to 750 atmospheres. The pressure thus stated can be readily converted into concrete quantities by multiplying the number of atmospheres by the actual atmospheric pressure at sea-level, viz., $14\frac{3}{4}$ lbs. per square inch.

84. At first sight, the enormous pressure of water at great depths seems almost to justify the old notion that the lower strata of water in the open ocean are so dense, in consequence of the great pressure, that the heaviest substances would never fall to the bottom, but would be buoyed up by the heavier and denser bottom-water. We have already (Art. 71) shown the absurdity of this notion, founded on the supposition that the density or specific gravity of the water increases proportionately to the pressure. The density certainly does increase, but in a fractional degree only. Thus, at a depth of one mile, under a pressure of 2,320 lbs. on the square inch, the water is compressed only $\frac{1}{114}$ of its bulk, and had there been a depth of twenty miles, the compression would then amount to only $\frac{1}{7}$. We thus find that, in spite of an enormous pressure or "dead weight" at various depths, the all but incompressibility of the water prevents any considerable increase in the density or specific gravity; and that this increase in density, consequent on increased pressure, is so slight as scarcely to affect any calculations of the weight of the water, even at the greatest depths. This distinction is a most important one, being, as it

were, the key to the otherwise insolvable problem of the continued existence of delicate organisms under the enormous pressure at the depths of the sea.

Form of Sea Bottom.

85. Reasoning by analogy alone, we would infer that the visible and invisible portions of the earth's outer crust must, generally speaking, present the same characteristic features of conformation; that the irregular elevations and depressions, mountains and valleys, plateaux and plains of the land, will have their counterpart in the relief of the far larger area covered by the waters of the ocean. In the absence of direct proof to the contrary, we would be inclined to believe that, were the vast mass of water removed, and the bed of the ocean laid bare, the scene that would meet our eyes would be but a repetition of the familiar sights on land: the same characteristic inequalities, probably intensified in proportion to the vastly larger area of the ocean—submarine plains and plateaux of vast extent, long mountain chains of enormous heights, and vast chasms of incalculable depths. And although our knowledge of the "depths of the sea" cannot as yet be said to be very extensive or absolutely accurate, yet sufficient information has been gathered, chiefly by the *Challenger* and other deep-sea exploration expeditions, as to enable us to form a tolerably correct idea of the general conformation of the floor of the ocean; the position, extent, height, and depth of all the larger elevations and depressions. The general results of recent researches prove (1) that there is some—though perhaps not very exact—relation between the heights of the land and the depths of the sea; the sea-level being, as it were, the relief-equator of the earth, equidistant from the highest elevation of the land and the greatest depth of the sea; and (2) that the sea-bottom does not, except in a few isolated instances, present abrupt descents and extreme inequalities like the land, but is, on the whole, gently undulating.

86. Generally speaking, the depth of water along the coast always corresponds, more or less, to the height of the adjacent land. If the land be low, the water will be shallow, but if it be high, the water will be proportionately deep. A gradual or gentle slope of the land towards the sea is always followed by a gradual increase in the depth of the water; the degree of inclination being, as it were, continued under the water for some distance. But if the coast be lofty and precipitous, sinking abruptly into the sea, the water deepens as suddenly and abruptly.—(See Fig. 1.)

(Fig. 1).—Section showing relation between height of coast and depth of water.

87. This "law of depth," or the correspondence between the height of the land and the depth of the water, applies only to the belt of water nearest the land, for it gives no clue whatever to the actual depth of the more distant and open areas; but though the areas to which it may be applied are limited, it is nevertheless remarkably true for those limits. Striking instances are found in every part of the world. Thus the level lands on the eastern coasts of England are bordered by the shallow waters of the North Sea. The lofty coasts of Norway, on the other hand, descend abruptly into correspondingly deep water. The vast plains of northern Asia shelve gradually into the shallow Arctic Ocean, while the lofty

southern extremities of Africa and America dip into the deep waters of the great Southern Ocean.

88. As we have already said, the general character of the bottom of the sea is "gently undulating;" the descent, even in the deepest parts, being by a gentle gradient. Occasionally the slope is very abrupt, but the extreme irregularity, so common on land, is confined to certain areas where there are vast coral reefs rising almost perpendicularly out of the ocean, or where the normal regularity of the ocean floor has been broken by violent volcanic disturbances, resulting in precipitous upheavals or subsidences. With these exceptions the floor of the ocean is far more regular than the surface of the land; there being, generally speaking, no extreme irregularities as on land, although that must have been the case at one time, when the present sea-bed was dry land, and consequently subject to active denudation.

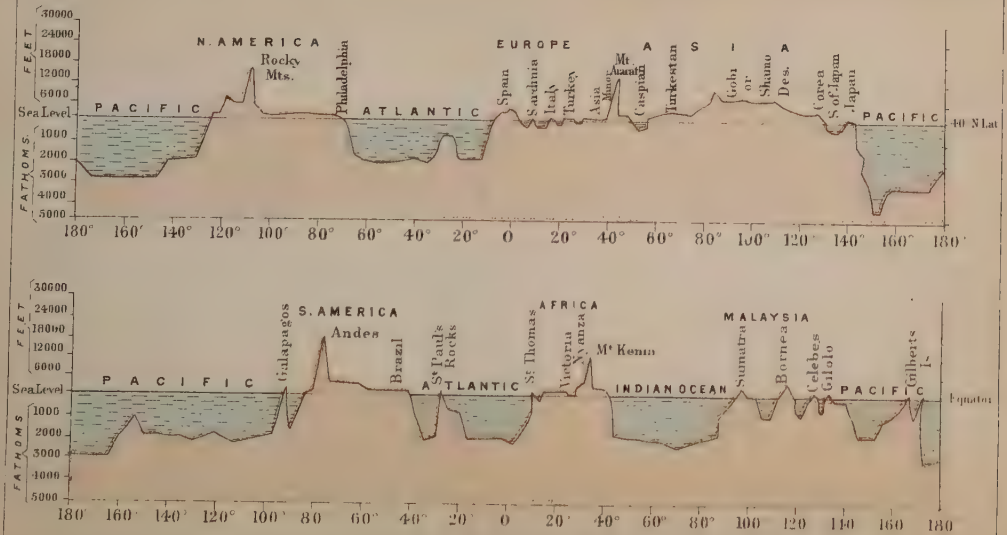
89. How, then, can we account for the present regularity of the sea bottom? The idea that it has been "planed down," as it were, by vast deep-sea currents, is absurd: for would not their action produce the very irregularities which they are supposed to have removed? Besides, it is now well known that, although there is undoubtedly a "set" of the water along the bottom of the ocean (generally from the poles towards the equator), yet the movement is very slow, and scarcely perceptible. This secular movement, the "creeping flow" of polar waters along the ocean floor, can hardly be called a current, and it certainly has no denuding action—otherwise the light fleecy-like deposits of calcareous and silicious shells which cover a large part of the sea-bottom, and into which the sounding-weight sinks several feet, would have been either washed away, or so mixed and triturated that the tiny delicate shells of the *foraminifera* would have been ground to powder; instead of which the specimens brought up are very frequently perfect, and scarcely mixed with any other foreign matter —thus suggesting most forcibly the idea of "perfect repose

at the bottom of the deep sea." The comparative smoothness of the floor of the ocean is most probably due to marine erosion during repeated submergences; and, since its resumption of its present position, the deposition of matter eroded by waves, or brought down by rivers, and distributed by currents—combined with a constant shower, as it were, of the calcareous and silicious shells, and skeletons of myriads of marine forms of life with which the ocean teems from the surface to its lowest depths—which would gradually fill up and cover any extreme irregularities which still existed. And the same process is going on unceasingly—hour after hour the floor of the ocean is constantly strewn with the materials of future continents.

90. The position, direction, and extent of the principal submarine elevations or "ridges" may be *approximately* marked by connecting the lines of islands in each ocean—islands being, in fact, but the visible summits of submarine mountains. Such a ridge, frequently rising above the surface of the water, may be traced in the Aleutian Islands, extending in an unbroken chain from Alaska to Kamtchatca. A not less striking example occurs in the West India Islands, enclosing the Caribbean Sea. A few points of the long ridge in the South Atlantic rise above the surface in the islands of Ascension, St. Helena, St. Paul, the Azores, and others. The *continuity* of chains or groups of islands, therefore, proves the existence of submarine mountain chains, of which the islands are the highest summits.

91. As we shall again describe the "bed" of each of the great oceans separately, we shall not pursue the subject further here; but we must remind the student that, unless he bears in mind the fact that sections of the sea-bottom are scarcely ever drawn to a true scale, he will be in danger of forming exaggerated notions as to the real conformation of the floor of the ocean. Being intended chiefly to show the exact depth at any given place, the actual proportion of the vertical and horizontal

To face page 61



Approximate Section of the World, shewing elevation of the land and depth of the Sea along the parallel of 40 N. Lat. and the Equator.

measurements are disregarded, the vertical height being greatly exaggerated, so that what looks in the section almost a perpendicular declivity, is in reality a gentle slope. This is unavoidable, especially in sections of large tracts of the sea, for the horizontal distances are so much in excess of the vertical depth, that they could not be conveniently shown in their actual relation on a true scale. Thus a section of the Atlantic, from Sandy Hook to Bermuda, 700 miles distant, showing a maximum depth of 2,850 fathoms, by a vertical line $3\frac{1}{2}$ inches in length, would have to be five feet wide if drawn to a true scale. In the accompanying sections those of the Atlantic present apparently almost perpendicular descents, but actually, if it were a mere question of gradients, a waggon could be driven along the bottom of the sea from Ireland to Newfoundland without any difficulty.[1] As the best preventative against forming incorrect and exaggerated ideas of the shape of the sea-bottom, the student would do well to select the most irregular portions of the sections given, and draw them to a true scale. This can be easily done by marking off the horizontal and vertical distances from the *same scale*, say $\frac{1}{10}$ or $\frac{1}{5}$ of an inch to the mile.

[1] Professor Huxley.

V.

DISTRIBUTION OF MARINE LIFE.

92. The sea as well as the land teems with animal and vegetable life, different of course in form, but, on the whole, similarly distributed; and the higher forms, at least, affected by the same climatical conditions. There is, however, this great distinction, that the highest elevations of the land are entirely destitute of either vegetable or animal life, while the lowest depths of the sea are the abode of myriads of marine animals; of generally lowly forms it is true, but still some with the most delicate organization. Naturalists, not so long since, implicitly believed in a "zero" of marine life—that is, the conditions at great depths were such that no organism could possibly exist, and therefore, the depths of the sea were utterly devoid of life, either animal or vegetable. But this notion has been entirely dispelled by recent researches, which prove that the "sea-bottom is inhabited by a rich and varied fauna."

Distribution of Marine Vegetable Life.

93. The distribution of plants on land is fixed by the conditions of soil and climate; the greatest profusion being within the tropics, and gradually disappearing *horizontally* towards the poles, and *vertically* to the limit of perpetual snow. Marine vegetable forms are similarly distributed, both horizontally and vertically. The prevalence of peculiar species within particular limits, permits of both the horizontal and vertical distribution to be broadly divided into more or less well-defined zones. Thus, horizontally, the *fucus* abounds in the North

Atlantic, the *sargassum* in the tropical regions of the Atlantic and Pacific.

94. Vertically, the conditions of distribution are different, but scarcely less decided. On land the temperature decreases as the elevation increases; but in the ocean there is a gradual fall of the temperature from the surface to the bottom. And as the height of the limit of perpetual snow decreases from the equator towards the poles, so also, but perhaps not so regularly, the limit of cold water, nearly ice-cold along the bottom, even under the equator, rises gradually until it reaches the surface at the Arctic and Antarctic Circles. But vegetation would seem to suffer more from the exclusion of light than from any other cause, light being absolutely necessary to their continued existence. The sun's light penetrates but a comparatively small depth, there are therefore few plants at a depth of 50 fathoms, and none at 200 fathoms. The depths to about 100 fathoms (600 feet) have been broadly divided into zones, each zone having its peculiar plants. Thus the dulse and bladder-wrack abound in the *littoral* zone, as the space between high and low water mark is called; while the tangle and scarlet sea-weeds characterize the *laminarian* zone, from low-water mark to a depth of 50 feet. The common sea-weeds decrease, and the corallines increase to a depth of about 300 feet. Lower still, to about 600 feet, is the *coral* zone. Except the microscopic vegetable forms called *diatoms*, the great depths of the sea are utterly devoid of vegetable life.

Horizontal Distribution of Marine Animal Life.

95. The horizontal distribution of marine fauna is, like that of the land, dependent primarily upon climatic conditions. Thus the shark and sperm whale exist in the tropical and temperate seas, while the right whale frequents the colder northern seas. The herring, cod, and other edible fish abound in the temperate zones only; while the walrus, rorqual, nar-

whal, and various kinds of seals, inhabit the icy-cold polar waters. Other kinds are peculiar to certain areas, as the tunny in the Mediterranean, &c. The various forms of marine animal life are generally limited as to their range, similarly to the fauna of the land; but the greater facility of intercommunication throughout the ocean prevents such an arbitrary restriction as on land. Thus we find the right whale and the sperm whale frequenting the same ground, although the former is essentially a polar, and the latter a tropical, animal. Still, a broad division of the ocean into zones of generally similar forms of life is not only possible, but also convenient, and indeed necessary.

96. The *homozoic zones* into which Professor Forbes divided the ocean can only be simply enumerated here; further information will be found in Mr. Forbes' "Natural History of the European Seas." In the northern hemisphere the zones are:—(1) The *median zone*, included within the tropics, inhabited chiefly by essentially tropical forms. To the north of this zone is (2) the *circumcentral zone*, narrow and irregular, embracing a limited belt in the Atlantic north of 30° N. lat., and including the Mediterranean, Black Sea, Caspian, and Sea of Aral, and continued across the Pacific, from Japan to California. (3) The *neutral zone* includes a gradually widening belt of the Atlantic, from the American coast to the western shores of Great Britain, and continued in the North Sea and Baltic. The special species in this zone is the herring, while in the next zone—(4) the *circumpolar* (embracing the tracts in the northern sweep of the Gulf Stream, towards Iceland and Norway, and a similar belt in the Pacific)—the cod-fishery is mainly carried on. (5) Within the *polar zone* is included the Arctic seas, inhabited by the right whale, seals, and other Arctic marine fauna.

Vertical Distribution of Marine Animal Life.

97. The vertical distribution of marine animal life is similarly shown by a broad division into *bathymetrical zones* of various depths. The mussel, cockle, periwinkle, &c., are found within the limit of high and low-water; the star-fish, sea-urchin, and other forms, abound in water 50 feet deep; while the oyster, various forms of star-fishes, and a host of other marine animals, exist in still deeper water. Until recently it was believed that, at a certain depth, there was a "zero of life"—that at great depths the conditions were such that no living organism could possibly exist. But the *Challenger* and other expeditions have proved conclusively that animal life is abundant, even at the greatest depths. "The sea-bottom is inhabited by a fauna more rich and varied, and with organisms in many cases even more elaborately and delicately formed, and more exquisitely beautiful in their soft shades of colouring, and in the rainbow tints of their wonderful phosphorescence, than the fauna of the well-known belt of shallow water, teeming with innumerable invertebrate forms, which fringes the land."[1]

98. The conditions under which these delicate organisms exist are certainly striking. We have already noticed the enormous pressure of water even at moderate depths. But the most delicately frail organisms may, by reason of their tissues being of the same density as the surrounding water, be not incommoded in the least by the pressure, even at the greatest depth, enormous though it must be; but how are they supported? and whence do they derive their nourishment? There is certainly, at a comparatively small depth, a total absence of light, and consequently of vegetation. The great distinction between an animal and a vegetable is, that the latter only has the power to convert inorganic matter for

[1] Sir C. Wyville Thomson.

its own nutrition, and that the animal is dependent for its subsistence upon this power of the vegetable of converting inorganic into organic matter. The total absence of vegetation, concurrently with the most prolific animal life, in the depths of the sea, most probably suggested the idea that the foraminifera, sponges, &c., found at great depths, have the power of directly converting the inorganic matters dissolved in the waters of the ocean for their own nutrition.[1] Many of them certainly do draw their supplies of carbonate of lime or silica for their shells directly from the water in which it is dissolved, and they may probably abstract and convert other inorganic matters in solution in the water. A high authority on the subject supposes that the minute forms which teem in the depths of the sea are supported by absorbing the animal matter, of which an immense quantity must be suspended or dissolved in the water.

99. The conditions of pressure at great depths, considered in relation to the delicately-formed organisms teeming therein, are indeed extraordinary. The graphic illustration given by Sir C. Wyville Thomson shows the actual amount of pressure better, perhaps, than a mere abstract statement. That at 2,000 fathoms a man would bear on his shoulders a weight equal to 20 locomotive engines, each with a long train loaded with pig iron, is almost incredible; yet millions of delicate marine forms bear, seemingly without the least difficulty, a pressure far exceeding this—and they not only bear it, but it is apparently absolutely necessary to their continued existence, for nearly all the specimens dredged up from the bottom were either dead, or dying, when brought up to the surface. The fresher and lighter surface water may certainly have affected them, but it is more probable that they died because the normal pressure was reduced. Even sharks, dragged up in Setubal Bay from depths of about 500

[1] Wallich.

fathoms, were dead *before* they reached the surface.[1] Now it is well known that human beings exist best under ordinary atmospheric pressure—that is, 14¾ lbs. on the square inch; but even this pressure, if exerted in any other way, would crush the strongest man to death. And yet, if this pressure be sensibly reduced, as on the higher mountains, mere existence is a matter of difficulty, while if it be still further reduced, death is certain to ensue. Reasoning by analogy, then, we conclude that the enormous pressure of the water under which the marine forms live in depths of the sea, is as necessary a condition of their existence as the ordinary pressure of the atmosphere is to human beings and land animals generally.

---

[1] Wright.

VI.

TEMPERATURE OF THE OCEAN.

Introduction.

100. Although water, of all substances, has the greatest capacity for heat—or, in other words, has the highest specific heat—yet it is a bad conductor of heat. Thus heat applied to one part of a mass of water, is not transferred from atom to atom, as when applied to a piece of iron or other metal; but the particles of water first heated change their position, and are replaced by other particles, which are heated and displaced in turn, and so on until the whole mass is uniformly heated. Water is thus heated—or, in other words, the temperature of water is raised—by an actual transfer of all its particles successively to and from the source of heat. It will be thus seen that the greater amount of heat required to raise the temperature of water, and the distribution of that heat by convection only, makes the heating of large masses of water a very slow process. Compared with the land, water requires four times as much heat to raise it to the same temperature. The sea, therefore, is not so readily heated as the land; nor, on the other hand, does it cool so quickly when once heated. Consequently, the sea is, on the whole, more equable as regards temperature than the land—that is, the difference between the temperature of the sea during the day and at night, or in summer and winter, is not so great as that of the land. In summer the land has a generally higher temperature than the adjacent sea; but in winter the sea is, on

the whole, warmer than the land. The sea is thus a great "storehouse of heat," cooling the land in summer by abstracting and storing the very heat which is given out to warm the land in winter. This equability, or comparative invariability of the temperature of the sea, has a most beneficent influence on the climate especially of maritime countries, which are nowhere subject to the great *extremes* of heat and cold that characterize the climates of inland countries.

Temperature of the Ocean—Horizontal and Vertical.

101. Horizontally, the temperature of the ocean, like that of the land, depends on the amount of solar heat, and varies similarly with the latitude—being highest in the tropics, and falling away towards the poles. But the distribution of the temperature of the sea is far more even than on land. The surplus heat of one part of the land can only be conveyed to another colder region by variable aerial currents, while the heated waters of the tropical seas are actually transferred in vast constant currents from the equator towards the poles. So that, as regards surface temperature, the latitudinal distinctions which may be appropriately applied to the land are scarcely applicable to the sea,—the thorough co-mingling of the surface waters of the ocean, from the tropics to the polar regions, by a vast system of currents, resulting in a far more even distribution of heat. Still it is *generally* true that, as on land, so at sea, the temperature sinks from the equator towards the poles. Thus, in the equatorial part of the Atlantic, the temperature of the surface water ranges from 80° to 83° F., while that of the North Atlantic is from 44° to 54° F. The mean temperature of the surface water in the North Pacific is about 70° F., and in the South Pacific about 67° F. The waters of land-locked tropical seas are abnormally warm, their excess of heat not being readily diffused through the colder open ocean. Thus the surface temperature in the Gulf of Mexico is fre-

quently 88° F., and in the Red Sea 94° F. has occasionally been recorded.

102. Of the temperature of the depths of the sea nothing certain was known until recent years. Sir James Ross's researches in the Southern Ocean led him to conclude that a uniform mean temperature of 39½° F. would be found at depths varying from 7,200 feet at the equator—3,600 feet along the parallel of 45° S.—at the surface within the belt between the parallels of 56° and 59° S.—and at a depth of 4,500 feet along the parallel of 70° S.; although the surface at the equator was 80° F., and at 70° S. lat. only 30° F. The recent observations of Dr. Carpenter and Sir Wyville Thomson have entirely dispelled the idea of a uniform mean temperature of 39½° at varying depths from the equator towards the poles. It is now proved beyond all doubt that the temperature decreases gradually from the surface to the bottom, the lowest stratum of water, even under the equator, being icy cold, generally near—and not unfrequently below—the freezing point; and that, throughout the ocean, the stratum of water having a temperature above 40° F. is comparatively shallow, the mass of the ocean being of cold water from 40° F., to icy cold at 30° F. In the North Atlantic, in a line from Sandy Hook to Bermuda, (and consequently across the Gulf Stream), it was shown that the Gulf Stream, with a temperature of 75°, overlies a mass of water which quickly falls to 40° F., and gradually to 35.3° F. at the bottom, at a depth of 2,425 fathoms, or 14,550 feet; the mass of cold water, from 35° to 40° F., being about two-thirds of the whole. The general bottom-temperature of the North Atlantic is 35.3°. In the South Atlantic the temperature falls to 40° F. at a depth of 300 fathoms, or 1,800 feet; at the bottom there is an average temperature of 32.9°, or nearly 3° colder than in the North Atlantic. In the North Pacific the bottom-temperature is generally below 35° F.; and off Cape Otway, in the South Pacific, it falls to 32.5° F.; still further south

the mass of the water from a depth of 1,000 fathoms, or 6,000 feet to the bottom, was icy cold, being from 32° to 31° F.

103. The lowest layer of water throughout the ocean is thus nearly at, and occasionally below, the freezing point of fresh water, being, in fact, actually below the general temperature of the outer crust of the earth. If the mass of water at great depths be immovable, as formerly supposed, surely its temperature would, in course of time, approximate that of the crust it overlies. This cold bottom-water cannot, then, be anything but an influx from the Polar Seas of icy cold water, which, sinking below the warmer—and therefore specifically lighter—surface-water "creeps" along the floor of the ocean towards the equator. Whether this cold influx comes from the north or south, or if from both, in what proportion, is easily determined by a moment's consideration of the communication between the Arctic and Antarctic basins, and those of the other great oceans. The Pacific, for instance, is nearly landlocked on the north, and communicates with the Arctic basin only by a strait of no great width, and only 40 fathoms in depth. This channel being mainly occupied by a warm current from the Pacific *to* the Arctic, the under current of cold water *from* the latter is unimportant. The influx of cold bottom-water in the Pacific must therefore be from the Antarctic. On the south the basins of these two oceans unite broadly for thousands of miles, and, for the most part, uninterrupted by continuous submarine elevations.

104. In the Atlantic, on the contrary, communication with the Arctic is comparatively open, by Davis' Strait to the north-west, and the vast channel—divided into two unequal portions by Iceland—extending from the eastern shores of Greenland to Norway. That there is a "set" of the colder Arctic waters *into* the Atlantic, even along the surface, is proved by the fogs off Newfoundland, formed by the impact of the polar currents, from Baffin Bay and East Greenland Channel, on the still warm waters of the Gulf Stream. That

this cold northern water presses south along the eastern coasts of North America, is proved by the "cold wall," which is so distinctly marked off Massachusetts that a vessel may have her bow in warm, and her stern in cold, water. The surface waters of the channel between Iceland and Norway are apparently a north-easterly drift of comparatively warm water, *probably* a continuation of the Gulf Stream; but even here the "cold and warm" areas, found side by side, show that a cold stream from the Arctic moves not only along the surface, but also along the bottom, into the Atlantic. But while the average bottom temperature of the North Atlantic is 35.3 F., that of the South Atlantic is 32.9 F.; so that, while the Arctic influx is in some measure impeded by the ridges which form the northern boundaries of the North Atlantic, the South Atlantic communicates more freely with the Antarctic, and thus receives a greater inflow of the South Polar waters.

105. A remarkable fact in connection with the temperature of the ocean is, that the temperature of the water in enclosed basins is uniformly the same as that of the water at the summits of the surrounding ridges. Thus, in the Sulu Sea, the temperature decreases from 84° F. at the surface to 50.5° F. at 200 fathoms. In the adjacent China Sea the surface temperature and that at 200 fathoms is the same—viz., 84° and 50.5° F. But while the Sulu Sea preserves a uniform temperature of 50.5° F. from 200 fathoms to the bottom (1780 fathoms), the temperature of the China Sea falls from 50.5° F. at 200 fathoms to 37° F. at the bottom. This uniformity of temperature is probably limited to the minor tropical basins, no such invariableness being found in the larger oceanic basins; and is evidently due to the fact that the water in such enclosed basins, having no contact with water colder than that overlying them, must, sooner or later, acquire the same temperature.

VII.

MOVEMENTS OF THE OCEAN.

Introduction.

106. We have already (Art. 48) noticed the remarkable uniformity in the composition of sea water throughout the ocean—*horizontally*, from the equator to the poles ; and *vertically*, from the surface to the bottom. The composition of sea water certainly varies slightly with the latitude, depth, degree of evaporation, and precipitation, but the difference is so small that, generally speaking, the salts of the sea are equally distributed throughout the whole mass. Now, warm water has a greater dissolving capacity than cold water, consequently the warm waters of the tropical seas, bulk for bulk, hold a greater amount of saline ingredients in solution than the cold waters of high latitudes. Naturally, then, the waters of the Torrid Zone should be considerably salter than those of the higher Temperate and Frigid Zones. But the difference is not so marked as we might expect, being in fact merely fractional, and, as we have said, scarcely affects the generally uniform saltness of the ocean. And although several causes are almost constantly at work, tending to produce considerable local differences—such as active evaporation in one place, and heavy precipitation in another—yet the sea is very nearly as salt in the latter as in the former. The uniform salinity of the ocean must therefore be due to its incessant motion, by which its waters are thoroughly mingled together.

107. The movements of the ocean are naturally divisible into three classes, according to the manner in which they are produced. Thus aerial currents produce disturbances of the

surface waters of the ocean in the form of waves; while the sun and moon, but more especially the latter, by attracting the mass of water, unequally, produce a periodical "bulging out" of the water, thus forming the great tidal wave; while other movements, due partly to the prevailing winds, and partly to the differences of temperature and density, constitute what are known as currents. We shall therefore treat—(1) of the atmospheric movements, or *waves;* (2) of the sidereal movements, or *tides;* (3) of the proper movements, or *currents:* appending a few remarks on general oceanic circulation.

Atmospheric Movements, or Waves.

108. By the atmospheric movements of the ocean, we mean those surface disturbances produced by atmospheric currents or winds acting on the surface of the water. The "waves" thus produced are the simplest of all the movements to which the ocean is subject, and are easily explained. The cohesion of water being limited, its particles obey the slightest impulse; but water is also all but incompressible, therefore displacement in one place is necessarily accompanied by the occupation of an equal amount of new space—or, in other words, water can never be depressed at one point without being proportionately elevated at another. A current of air moving exactly parallel to the surface of the water does not produce the slightest apparent commotion, but if it strikes the surface, at however small an angle, the water at the point of impact will be more or less depressed, and consequently there will be a corresponding rise beyond. Thus a "wave" is formed, the elevation or height above the normal level being exactly equal to the depression below that level. If the wind continues to blow, similar depressions and elevations are formed in all directions, imparting a kind of undulatory movement to the surface water. These undulations or "waves" increase in magnitude in proportion to the force of the wind and the angle at which it strikes the water. A slight breeze passing over the water,

nearly but not quite parallel to the surface, produces small ripples; but heavy gales or sudden blasts agitate the water violently—the normally-level surface is literally seamed as with vast furrows, frequently 30 to 40 feet from trough to crest.

Waves—Nature of Motion.

109. It must be distinctly borne in mind that the motion imparted to the water by the impact of the wind at various angles is not progressive, although apparently so. The *form* of the wave moves, but not the water, that is, the *same wave* as it advances is not composed of the *same water*. The nature of wave-motion is very clearly shown by a common illustration. For instance, when a long carpet is shaken, waves or undulations are produced, which travel successively from one end to the other. Both ends are stationary, and no one would think for a moment that a single thread has—relatively to the other threads—changed its place. That a fixity of relative position may be preserved, and yet a wave-like motion be propagated is, perhaps, still more clearly shown when a breeze passes over a corn field. The same wave-like motion is produced, but not a stalk has permanently changed its normal position. The fixity of the component threads of the carpet, and the attachment of the stalks of corn to their roots, are, of course, stronger than the actual cohesion between the particles of water; yet the motion is almost precisely the same—that is, the motion of the wave is not attended by an actual permanent change in the position of its component particles. The "form" of the wave moves forward without any corresponding advance of the water; a wave being, in fact, simply a vertical or up-and-down motion of the particles of the water, which resume their original positions when the disturbing influence is withdrawn. That the motion is simply propagated along the surface, like the "waving" of a corn field, may be easily proved by throwing a cork on the water when slightly agitated by the wind. If the water

actually advanced, the cork would certainly be carried along with it, instead of which it simply oscillates up and down ; and if its bearings relatively to any fixed object on shore be accurately observed, it will be seen to retain the same position.

Different Aspects of Waves.

110. The term "wave" is applied indiscriminately to all undulations of the surface-water, whatever their magnitude or cause. Besides the wind, earthquakes, and the attraction of the sun and moon, also produce "waves," distinguished as wind-waves, earthquake-waves, and tidal-waves, respectively. Atmospheric disturbances are, of course, the direct cause of *all* wind-waves ; still, the varying force of the wind, and the different angles at which it strikes the water, produces different aspects of the water. Thus the slight ripple produced by a gentle breeze is called by sailors a *catspaw*. A continuous wind, rising to a heavy gale, produces a *swell* or *billow* in the open sea, converted into *rollers* or *breakers* as they near the coast. The effect of violent storms, in certain localities, is propagated for great distances in the regular heaving motion known as a *ground swell*, which does not cease for some time after the storm is over. Occasionally the wind, after blowing steadily for some time in a certain direction, suddenly changes. Thus two series of waves are produced : the second crossing the first at different angles, and resulting in a peculiar trellis-like appearance of the water, nautically known as a *chopping-sea*.

111. So long as a wave passes over deep water, it simply rises and falls vertically—the form only advancing ; but as it approaches the shore, its lower part is checked by friction on the bottom, consequently its upper part moves faster, and is converted into a *wave of translation*, or an actual forward motion of the water. The confused, broken water along a shallow coast, formed by the actual advance of the waves, is called a *surf*. The heavy surf on exposed coasts, such as on

the western coasts of Africa, and the Malabar coasts of India, renders landing at all times difficult, and often dangerous. Such is the force of the water, that even "great sharks, lying in wait for their prey, are destroyed by the breakers, and are themselves overwhelmed in its fury, and dashed lifeless on the beach."—*(Skertchley.)*

Waves—Their Magnitude, Velocity, and Force.

112. The magnitude of waves is generally greatly exaggerated, the expression "mountains high" being often used. But it is proved that even the largest billows do not *disturb* the water at a depth of more than 300 feet; the wave itself being only a sixth of this. As we have already explained, the depth of the *trough* below the general level is always equal to the *height* of the *crest* above it. The "height" of a wave is calculated from its trough to its crest, the "width" being the distance between two successive crests. The magnitude of waves depends, of course, on the force and continuance of the wind, and varies from a mere ripple to huge billows of 30 and 40 feet high. The largest waves known are formed during a strong north-west gale off the Cape of Good Hope, when they are often 40 feet from trough to crest, while off Cape Horn waves of 30 feet have been frequently observed. In the North Atlantic the highest do not generally exceed 20 to 25 feet, but some 36 feet high have been seen in the Bay of Biscay. In the shallow North Sea, wind-waves scarcely ever exceed 8 to 12 feet in height, though, during very severe storms, exceptionally high waves have been observed: for instance, in 1870 when the breakwater at Wick was destroyed, the waves must have been at least 40 feet high.

113. The *velocity* of waves does not imply the rate at which the *water* travels, but the rapidity with which the undulations are propagated. This of course depends on the force and velocity of the wind, modified by the depth of water over which the wave advances. It has been proved that there is a

definite relation between the magnitude and velocity of a wave and the depth of water in which it is formed. As will be seen from the following, compiled from that given by Sir G. Airy, the Astronomer-Royal, a wave 100 feet broad, passing over water 100 feet deep, has a velocity of 15 miles an hour.

Depth of Water in Feet.	Breadth of Wave in Feet.						
	1	10	100	1,000	10,000	100,000	1,000,000
	Velocity of Wave per Hour in Miles.						
1	1.5	3.6	3.8	3.8	3.8	3.8	3.8
10	1.5	4.8	11.5	12.2	12.2	12.2	12.2
100	1.5	4.8	15.1	36.3	38.6	38.6	38.6
1,000	1.5	4.8	15.1	48.8	115.1	122.0	122.0
10,000	1.5	4.8	15.1	48.8	154.2	364.0	386.4
100,000	1.5	4.8	15.1	48.8	154.2	489.6	1151.0

114. The *force* with which a wave strikes is directly proportional to its magnitude and velocity—the larger and swifter the wave the greater its force. Along the British coasts are many striking proofs of the enormous power of large waves. Huge blocks of 30 or 40 tons have been repeatedly displaced; strongly-built sea walls have been breached or utterly destroyed; even lighthouses—whose builders underrated the power of the waves—have been swept away. The actual force has been experimentally ascertained in several places. The average force on the west coast of Ireland is about 600 lbs. on the square foot, but occasionally, in severe storms, the pressure amounts to 7,500 lbs., or nearly $3\frac{1}{2}$ tons on the square foot! The total pressure to which the seaward faces of lighthouses, embankments, breakwaters, &c. are thus subject to, is therefore enormous: hence the necessity of compactness and great strength in all such structures.

VIII.

SIDEREAL MOVEMENTS OR TIDES.

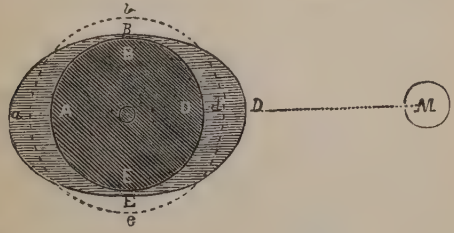
115. In Art. 2 we defined the term "sea-level" as the general level of the surface of the ocean, irrespective of the essentially surface-disturbances produced by winds, or the periodical rising and falling of the water known as the tide. Although wind-waves are occasionally of considerable height, yet they are local and temporary, affecting the surface only, and subside when the wind falls. But the tide is a movement that affects the whole mass of the water, which *flows* and *ebbs* every twelve hours. The tidal-wave is lowest in the uninterrupted open sea, and highest in more limited areas, especially in bays, gulfs, or channels opening broadly to its course, and gradually decreasing in width, such as the English and Bristol Channels. The height of the tidal-wave also varies considerably at different times, as well as in different places; but whatever the height of the wave, the elevation or *flow* above the general level is always equal to the depression or *ebb* below that level. As a standard of measurement for elevations on the land, or the depths of the sea, neither the high-water nor the low-water mark can be taken, but the mean between the two, which is always the same, whatever the variation in the height of the tide at different times and in different places. Thus the *datum line* of the Ordnance Survey of Great Britain is fixed at the mean tide-level at Liverpool.

Tides—Lunar and Solar.

116. The origin of the grand regular movement of the waters of the ocean, called the tide, may perhaps be more clearly

explained by supposing the earth to be entirely covered with uniformly-deep water, and then observing the effects of the attraction of the moon and sun on this aqueous envelope. The student must, however, first of all, have a clear conception of that species of attraction called gravitation, or gravity, which is universal—every particle in nature attracting every other particle. The fundamental laws by which the attraction of gravitation is governed, relate to (1) *mass*, and (2) *distance*. First, *the force of attraction between two bodies is in a direct ratio to their mass.* That is, the larger the mass of a body, the greater its attractive power. Secondly, *the force of attraction between two bodies is in an inverse ratio to the square of the distance;* or, in other words, the attractive power of bodies decreases proportionately to the distance. Thus, suppose three bodies of equal mass—*A*, *B*, and *C*, attract a fourth body, *D*. If *A*, *B*, and *C*, are at equal distances from *D*, their attractive power will be the same, since they are of equal mass; but if *A* be 250,000, *B*, 500,000, and *C*, 1,000,000 miles from *D*, their attractive force will be unequal, although their mass be still the same. Attraction diminishes as the square of the distance, therefore the attractive force of *A* will be four times as great as that of *B*, which is at twice the distance. The force of *B* will likewise be four times, and *A's* sixteen times, that of *C*. As, therefore, the attractive force of bodies is in a direct ratio to their mass, and decreases proportionately to the distance, a large body may exert a stronger attractive force than a much nearer but smaller body; and, *vice versa*, a smaller, but much nearer, body may attract another more strongly than a much larger, but more distant, body. Thus, supposing the mass of *B* to be four times that of *A*, both *A* and *B* would attract *D* equally, the greater distance of *B* being exactly balanced by its larger mass. Again, suppose *C* at four times the distance of *A* be only four times the size, then its attractive force on *D* would be only a fourth of that of *A*. Now the sun is 400 times further from the earth than the moon is, but his mass is nearly 28,400,000

times greater. If the sun's mass were equal to that of the moon, the earth would be attracted by the sun and moon in the proportion of 1 to 160,000: that is, the attraction of the moon would be 160,000 times greater than that of the sun, supposing their mass to be equal. But as the sun is 28,400,000 the size of the moon, its mass is so vastly greater, that the difference in distance is more than balanced. The sun therefore attracts the earth *as a whole* much more strongly than the moon does. We are now in a position to understand clearly the effect of the solar and lunar attraction on the earth. Let us consider that of the moon first, still retaining the supposition that the earth is entirely covered with uniformly-deep water.



117. As the earth revolves on its axis once every twenty-four hours, every part of its surface is successively brought under the direct action of the moon *once* a day. But the tide ebbs and flows *twice* a day, whereas if the tide were due to the simple attraction of the moon on the side of the earth nearest to it, there would only be *one* tide a day. This apparent ambiguity is easily explained. In the above diagram, the shaded circle represents the solid earth covered by uniformly-deep water, *a*, *b*, *c*, *d*, and *M*, the moon. But the attraction of the moon destroys the uniformity of the aqueous covering of the earth, for the latter has a diameter of nearly 8,000 miles, and

the moon is only 240,000 miles distant—it is evident that the *difference* in the moon's attraction on the opposite sides of the earth will be very considerable. Both the solid and liquid portions of the earth are equally attracted in proportion to their distance, but the limited cohesion of the water allows it to respond to that attraction differently to the solid part, which can only move as a whole. The waters, therefore, on the side towards the moon, are drawn off from *b* and *e* towards *d*, and finally culminate at the point *D*. This bulging out at *D* is, then, due to the difference in the force of the moon's attraction on the water *b*, *d*, *e*, and on the solid crust B, D, E,—the water alone being free to move, is drawn towards the point of maximum attraction. Similarly, the moon's attraction on the opposite solid crust B, A, E, will be greater than on the water *b*, *a*, *e*; and as the solid part can only move as a whole, A, B, D, E, approaches *M*, leaving the water behind, as it were, at *A*; so that here it bulges out exactly as at *D*. And as the waters culminate at *A* and *D*, they are drawn off from *b* and *e*, and finally sink to *B* and *E*. Supposing, then, that the earth were uniformly covered with water, and subject only to the moon's attraction, two tides would be formed—one on the side nearest the moon, and one on the opposite side—the culminating point in each being in the direct line of the moon's action. And as the earth revolved on its axis, the tidal waves thus formed would make the complete circuit of the globe once a day.

118. But the earth is attracted by the sun as well as the moon; and, as regards absolute amount, the solar attraction is much greater than the lunar. That is, the earth as a whole is far more strongly attracted by the sun than the moon; and if the tides were formed by the mere attraction of the sun and the moon, the solar tide would be much greater than the lunar. But the moon's tide-producing power is $2\frac{1}{2}$ times greater than the sun's—the tide being produced not by the attraction of the sun or moon on the earth as a whole, but by *the difference of*

their attraction on different parts of the earth. The total attraction of the sun is vastly greater than that of the moon, but the *difference* in the attraction of the moon on different parts of the earth is greater than the difference in the sun's attraction. Independent of the moon, the sun would produce a tide $2\frac{1}{2}$ times less than the lunar tide; and as both the sun and the moon act on the earth at the same time, but in continually varying directions—the solar tide is undistinguishable from and merged in the lunar. When the sun and the moon are on the same or opposite sides of the earth, so that their attractive power is exerted in the same line, the solar and lunar tides are combined, thus producing the greatest possible "flow" of the water, known as *spring-tides.* Spring-tides are formed both at new and full moon. But when the moon is in her first or last quarter, that is, 7 or 21 days old, her attraction is diametrically opposed to that of the sun. Consequently, the solar tide neutralises the lunar to some extent, and thus the lowest possible tides are formed, known as *neap-tides.* Spring-tides are thus the sum, and neap-tides the difference, of the solar and lunar tides.

119. The rotation of the earth on its axis brings every meridian successively under the sun and the moon. But while the sun is relatively to the earth immovable, passing over every meridian regularly in 24 hours, the moon travels eastward, in her monthly circuit, round the earth. The earth, therefore, must make somewhat more than a complete rotation before the moon is again over a given meridian. Thus, while the solar day is 24 hours, the lunar day is 24 hours 54 minutes, and as the moon is the principal agent in producing the tide, the *flow* and *ebb* will not occupy exactly six hours each time, but high-water will occur about 50 minutes later each day than on the previous day. Another fact which must not be overlooked is, that high-water does not occur even in the open ocean at the exact time of the moon's passage over a given meridian, but always about two hours after. Similarly both

spring-tides and neap-tides do not occur exactly when the moon changes, or at full-moon, but a day or two later.

TIDAL-WAVE—FORMATION, DIRECTION, AND VELOCITY.

120. If the earth were uniformly covered with water, the tidal-wave would flow regularly every lunar day from east to west—highest directly under the moon, and lowest 90° on either side. But the continuity of the ocean is broken by the intervention of the land masses, the only uninterrupted expanse being a belt between 30° and 70° S. lat., where the deep waters of the Southern Ocean extend right round the globe; and it is here that the true tide-waves are originally formed, and as they advance westwards are deflected, first into the Indian, then into the Atlantic Ocean. Minor tides may, probably, be generated in the tropical parts of all the great oceans, especially the Pacific, but the true tidal-waves in every part of the ocean receive their primary impulse in, and are propagated from, the Southern Ocean.

121. The progress of the tidal-wave may be marked on a chart by a series of lines connecting all places whose "establishments" are the same. These lines, called *co-tidal lines*, show the path of the great tidal-wave from its origin in the Southern Ocean to its final subsidence in the remote Northern Seas. In examining the accompanying map of co-tides, it must be remembered that the tides in the Atlantic and Indian Oceans are simply the continuation of the tidal-waves formed in the Southern Ocean, between Cape Horn and Balleny Islands. Off Van Diemen's Land it is high-water at 12. The tidal-wave, moving more and more obliquely to the coast, passes Cape Leeuwin at 5. Seven hours later it reaches Ceylon, and at 1 it deflects past the Cape of Good Hope into the Atlantic. Pressing up the Atlantic, at first in a south-westerly direction, it crosses the equator, and, inclining more to the north-west, appears off Newfoundland and Cape Verd 13 hours after passing the Cape of Good Hope. Four hours later the wave extends from the south coast of Iceland, by the south-west of Ireland, to Cape Ushant in France. It then divides

CHART SHOWING COTIDAL-LINES.

In face page 87

George Philip & Son, London & Liverpool.

into three branches—the main branch sweeping along the western coasts of Ireland and Scotland, and dividing off the north of Scotland, one turning south into the German Ocean, the other proceeding north along the coast of Norway, reaching North Cape in 10 hours. The second branch presses through St. George's Channel into the Irish Sea, and meets a minor tide-wave from the north, off Courtown on the north-east coast of Ireland. The third branch proceeds up the English Channel, arriving at Dover in 7 hours, and meeting the northern tide-wave in the German Ocean off the mouth of the Thames. It will be readily seen that the tides are considerable only in areas open to the general course of the tidal-wave from the Southern Ocean; for this reason the Mediterranean and other inland seas are almost tideless.

122. The *velocity* of the tidal-wave is greatest where it passes over the deepest and most open water. In the Southern Ocean it attains a velocity of 1,000 miles an hour, but in more limited and shallow areas, such as the North Sea, it scarcely travels 50 miles an hour. The absolute *height* of the tide is considerable only in channels or inlets opening broadly to its course, and gradually getting narrower. In the open Southern Ocean the wave is scarcely six feet high, in the Indian and Atlantic Oceans about ten feet; but in such a *cul-de-sac* as the Bay of Fundy or the Bristol Channel, it rises to 50 or 60 feet, and forms an impetuous *bore* or head of water, advancing with great rapidity. All rivers whose estuaries are open to the course of the wave are tidal rivers, and frequently the ascending wave attains such a height and velocity as to be dangerous, and often most destructive. Thus the tidal-bore of the Tsientang River, in China, rushes up the river in huge waves 30 feet high, at a rate of 25 miles an hour. In the Bristol Channel the wave is pressed into a narrowing channel, and rises at Chepstow to nearly 40 feet, and thence forms a bore 8 or 9 feet high, which ascends the Severn rapidly to a considerable distance. Such bores also occur in the Hooghly, Garonne, Amazon, and other rivers.

IX.

PROPER MOVEMENTS, OR CURRENTS.

Introduction.

123. However violent the wind, the "waves" it produces scarcely ever exceed forty feet from crest to trough, and are therefore essentially surface-disturbances. The "tides," on the contrary, are the result of an attraction, exerted chiefly by the moon, and affecting the whole mass of the water. Wind-waves are also virtually local and temporary, depending on a constantly fluctuating cause, while the tides are periodical, regularly flowing and ebbing twice a day. Waves and tides are thus two distinct movements of the waters of the ocean—the former all but constantly varying, the latter recurring regularly and uniformly; but the nature of the motion in each case is exactly the same—both wind-waves and tidal-waves are mere undulations, or up-and-down movements of the water, without any *progressive motion*. As we have already explained in Art. 109, the *form* of the wave alone moves, and not the water. Occasionally, indeed, a purely undulating movement of the water is converted into a "wave of translation," as along shallow coasts, or in narrow inlets. A wind-wave may be propagated for hundreds, and a tidal-wave for thousands, of miles, yet the nature of their motion is such that a floating substance would move vertically only, simply rising and falling with the undulation, but retaining the same actual position. But leaves, fruits, and branches of tropical plants are often found scattered along the shores of remote northern seas, and must therefore have been "drifted" from the equatorial regions towards the poles.

This fact alone would suffice to prove that there must be a progressive motion of the water itself, otherwise there could be no actual transference of substances from one place to another. That there is a movement of the sea other than waves and tides has been practically proved in many ways. Sailors often enclose a piece of paper, with the date and position written on it, in a bottle, which is then thrown overboard. Numbers of bottles thus consigned to the sea have been found hundreds and thousands of miles distant from the place where they were thrown over. Some are soon cast ashore; others move freely about for many years. Maury says of one bottle thrown over off Cape Horn being picked up on the coast of Ireland more than twenty years after. Of two others, thrown overboard in the South Atlantic, off the coast of South Africa, one was found at Trinidad, in the West Indies, and the other was picked up on the coast of Guernsey, in the English Channel. Most probably both journeyed together towards the West Indies, where one was cast ashore, while the other pursued its course eastwards across the Atlantic and up the English Channel to Guernsey. In this way alone a pretty accurate notion of the general drift of the sea in different localities could be gained, but, the commencement and end of the journey of each bottle being known, its course could only be imagined. And as a thorough knowledge of the "rivers of the ocean" is most important to the navigator, these currents and drifts have been minutely traced and investigated; and instead of being, as formerly, regarded with doubt and fear, their position, direction, and velocity are now so well known, that a voyage may be materially shortened by eluding unfavourable drifts, and taking full advantage of the "flow" in the direction of the wished-for port. The various drifts and currents that thus retard or increase the speed of vessels, constitute what is termed the *horizontal circulation* of the waters of the ocean. As we shall again see, there is also a *vertical circulation*, or a gradual interchange of the whole mass of the ocean from the surface to the lowest

depths. The study of the latter is certainly most interesting, but that of the former is not only theoretically interesting, but is also of vast practical importance; its axioms being daily and hourly applied in "shaping the courses" of thousands of vessels speeding across the boundless "world of waters."

Classification of Currents.

124. By the term "oceanic circulation" is meant the whole of those progressive movements of the water generally called *currents*. But several causes tend to produce different aspects of these as well as other movements of the ocean. Thus *constant currents*, or *stream currents*—as they are sometimes called, from their analogy to "streams" on the land—are virtually perennial "rivers in the ocean," regularly flowing in the same direction at all times; while *periodical*, or *variable currents*, change their direction periodically, or at uncertain times, in obedience to similar changes in the direction of the prevailing winds. The distinction between *deep-sea currents* and *drift currents* is implied in the terms used—the latter being merely a "set" of a shallow layer of the surface water, while the former are constant currents of considerable depth. *Surface currents*, also, generally overlie *under-currents* flowing in a different direction. Of two related currents, the principal stream is called the *current*, in contradistinction to the return stream or *counter-current*. The student must also bear in mind that marine currents are named differently to air currents. Winds are named according to the direction *from* which they blow—thus an "east wind" is a wind blowing from the east. Currents, however, are named according to the direction in which they are flowing. Thus a current flowing *to* the north is called a "northerly current."

OCEAN-CURRENTS.
The Arrows show the direction of the currents.
Arctic Circle
Arctic Current
Davis Strait
Greenland Current
Gulf Stream
Sargasso Sea
Equatorial Current
Brazil Current
Mexican Current
Tropic
Equator
Equatorial Current
Equatorial Current
Tropic
Equatorial Current
Equatorial Current
Equatorial Current
Atlantic Current
Equatorial Current
Equatorial Current
Equatorial

General View of the Currents of the Ocean.

125. As the subject of "oceanic circulation," and more especially the causes of ocean-currents, cannot be discussed without referring frequently to particular currents, the student should, therefore, have some knowledge of the position and direction of the principal currents before attempting to investigate their origin. The accompanying chart shows clearly the position and direction of the chief currents, and should be carefully studied. Commencing in the south, we have a general drift of the cold waters of the Antarctic Ocean into the Pacific —from New Zealand to Cape Horn—where the drift divides, one branch flowing round it eastwards into the Atlantic, while the other proceeds along the western coast of South America as the *Peruvian current*, and finally merges into the southern portion of the *equatorial current* of the Pacific, which sweeps across to the Malay Archipelago. One branch, the *Japanese current*, runs north-east along the coasts of China and Japan, and, extending to the opposite shores of North America, is then deflected south. A portion of this current forms the *Mexican current*, which runs along the Mexican coast to the equator, but the main stream curves to the west, forming the northern portion of the equatorial current. The numerous streams pressing from the Pacific into the Indian Ocean, through various channels in the East Indian Archipelago, combine and form a similar northern and southern equatorial current. The former sweeps through the Bay of Bengal and the Arabian Sea, in a westerly or easterly direction; the latter curves south along the African coast, passing through Mozambique Channel towards Cape Agulhas. A branch of the latter current curves south-west by the Mauritius, and, pressing along the eastern coast of Madagascar, unites with the main current. The combined stream now flows towards the Cape of Good Hope as the *Agulhas current*, one portion of which holds on its way up the Atlantic into the great equatorial current, while the

remainder is turned back as a southern connecting current from the Atlantic into the Indian Ocean. The *Atlantic equatorial current* sweeps to the west, and deflects off Cape St. Roque, one branch turning south along the Brazilian coast, while the other trends north-west into the Caribbean Sea and the Gulf of Mexico, whence it issues as the celebrated *Gulf Stream*. This vast current was formerly supposed to hold on its way to the British and Norwegian coasts; but the real current becomes diffused and scarcely recognisable a short distance off Newfoundland. The warm waters that bathe the coasts of north-western Europe are, most probably, a general drift of the Atlantic water towards the north-east. A perceptible drift south, between the Azores and the Spanish coast, acquires a more marked character, as it gradually trends south by Madeira and the Canary Islands, and forms the *Guinea current*, which, following the curves of the African coast, finally unites with the great equatorial current. Two polar currents, also, flow into the Atlantic—one from Baffin Bay, through Davis' Strait, and another along the eastern coast of Greenland. Combining off Cape Farewell, this Arctic current curves by Newfoundland and flows along the American coast, forming a belt of cold water along the shore, bounded by the warm waters of the Gulf Stream, underneath which it finally sinks, entering the Mexican Gulf as an under-current through the Straits of Florida.

126. A few remarks as to the similarity between the principal currents in each ocean may serve to fix them in the memory. Thus the great equatorial currents of the Pacific, Atlantic, and Indian Oceans are all two-fold; the northern and southern branches being separated by a minor counter-current flowing east. The Gulf Stream of the Atlantic resembles in many respects the Japanese current of the Pacific. Both have a north-easterly direction; both terminate in nearly the same latitude; one portion of their water uniting with a general north-east drift, while the rest is deflected

off the opposite coasts into the equatorial currents. The Atlantic communicates with the Arctic by two broad channels, but the Pacific is nearly closed on the north, the only outlet being a strait of no considerable width or depth. Thus while the Atlantic receives the icy cold polar waters through Davis' Strait and East Greenland Channel, the comparatively shallow Behring Strait can only admit a limited amount of cold water from the Arctic into the Pacific, and is besides almost entirely occupied by a warm current flowing *to* the north. And as, from whatever part of the ocean a current runs, to that part an equal current must return,—all the great currents have compensating counter-currents. Thus the flow along the equator to the Mexican Gulf, in the Atlantic, is returned by the Gulf Stream and Guinea current; and the same equatorial flow in the Pacific is compensated by the equatorial counter-current, and the eastward extension of the Japanese current.[1]

Oceanic Circulation.

127. The remarkable uniformity in the composition of sea-water from the equator to the poles, and from the surface to the lowest depths, is undoubtedly a proof of a general and constant interchange of the waters of the ocean; for otherwise, owing to excessive evaporation in some localities, and excessive precipitation in others, the proportion of saline ingredients would vary considerably; and the causes of the difference being in many places almost constant, the variation would also be constant and increasing; so that in time some parts of the sea would be nearly, if not quite, fresh, while other parts would be excessively salt. But the saltness of the water is very nearly the same throughout the ocean. There must be, therefore, an actual interchange, or "circulation," of the waters of the ocean.

[1] The student is strongly recommended to consult the map, showing the ocean currents, given in *Hughes' Atlas of Physical Geography.* (George Philip & Son.)

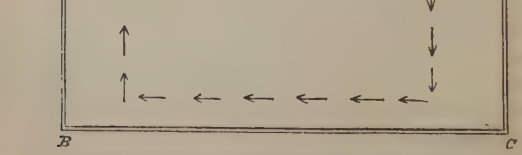
128. The "drifting" of the bottles, drift-wood, and other marine débris (Art. 123), practically proves the existence of currents at the surface of the ocean, constantly flowing in certain definite directions. Mariners have also not unfrequently observed immense icebergs moving rapidly against both the surface current and the wind. The submerged portions of the icebergs must therefore have been acted on by *under-currents* flowing in an opposite direction to the surface drifts. Recent researches show that the warm water even under the equator forms a comparatively shallow layer, overlying a mass of cold water, near and occasionally below the freezing point of fresh water, and therefore *actually below the general temperature of the earth's crust.* There must therefore be not only surface and under-currents to a moderate depth, but also a vast influx of cold water along the bottom from the poles towards the equator, being, in fact, a bottom inflow from the poles, compensating a surface overflow from the equator.

129. There is, therefore, such a thing as a general circulation of the waters of the ocean; but although its existence is beyond doubt, its cause or causes is as yet a moot point. One high authority[1] asserts that the general system of oceanic currents is produced by the winds,—not by the trade-winds alone, nor by the prevailing winds proper alone, but by the combined action of all the prevailing winds of the globe, regarded as one system of circulation. Dr. Carpenter, Keith Johnston, and others, assert that currents are caused by the difference of temperature of the polar and equatorial regions of the globe. But Sir Wyville Thomson says that "he has never seen, whether in the Atlantic, the Southern Sea, or the Pacific, the slightest grounds for supposing that such a thing exists as a general vertical circulation of the water of the ocean depending upon differences of specific gravity." Con-

[1] Dr. Croll (*Philosophical Magazine*).

stant aerial currents, such as the north-east and the south-east trade-winds, are most probably the cause of the westerly drift in the Atlantic and Pacific; but the general oceanic circulation is mainly owing to the unequal densities of sea-water, arising from differences of temperature or saltness.

130. Dr. Carpenter's theory is, that "a vertical circulation is maintained between the polar and equatorial waters by the difference of their temperature, the level of polar waters being reduced, and its density increased, by the surface *cold* to which it is subjected, whilst a downward motion is also imparted to each stratum successively exposed to it; and the level of equatorial water being raised, and its density diminished, by the surface *heat* to which it is exposed. The first of these agencies is by far the more effective, since it extends to the *whole depth* of the water, whilst the second only affects in any considerable degree the *superficial stratum.* Thus a movement will be imparted to the upper stratum of oceanic water, from the equator to the poles; whilst a movement will be imparted to the deeper stratum, from the poles to the equator." This theory is supported by two well known facts, viz.:—the general movement of the upper stratum of water in the tropics towards the poles, and the existence of a lower stratum of icy-cold water over the bottom of the great oceans, communicating with either or both of the polar seas. The following experiment clearly



illustrates this theory:—*A*, *B*, *C*, *D*, is a long trough with glass sides, containing some water. In one corner, *c*, a lump

of ice is placed. On the other end *A*, a piece of metal *ab*, is placed in contact with the water, and heated at one end by a lamp at *a*. A little *blue* colouring liquid is put into the water near the ice, and a little *red* colour near the hot metal. A continuous circulation in the direction of the arrows is the result. The end *A*, of course, represents the tropical, and *D*, the polar, regions. The effects of polar cold and tropical heat is thus clearly demonstrated, and had the earth been entirely covered with uniformly-deep water, subject to no other disturbing influences, a regular vertical and meridional circulation of the water would be manifest.

131. Besides unequal densities, other causes may, and most probably are, operating in the production and maintenance of oceanic circulation. The northern and southern branches of the great equatorial currents, in each of the three great oceans, are directly referable to the action of the winds. In the Pacific and Atlantic the trades generally blow in the same direction, and the great equatorial currents sweep along to the west; but in the Indian Ocean the currents north of the equator are regulated by the monsoons, and vary their flow accordingly. Were the earth uniformly covered with water, the effect of the prevailing winds on the surface of the water would be much more marked than it is; but the intervention of the land masses breaks the continuity of the ocean, and frequently changes the normal direction of the currents.

132. The bottom layer of water, of almost glacial coldness, is admitted to be an influx from the poles towards the equator. The generally-received opinion is, that this influx is due to the *sinking* of the surface water in the polar regions, owing to increased density produced by the extreme cold, and the *expansion* of the surface water in the tropics, owing to the extreme heat; thus creating a difference in level between the polar and equatorial seas. The equatorial waters being higher than the polar, they naturally flow towards the poles, but, on arriving in higher latitudes, gradually lose all their heat,

and finally sink to the bottom. But the *over*-flow from the equator must be balanced by an *under*-flow from the poles, and thus the cold bottom-layer of the ocean is simply polar water in transit towards the equator, where it slowly rises to the surface, and again flows towards the poles. And as the process of heating the surface water in the tropics, and chilling it in the polar seas, is constant, the overflow and underflow are constant also.

133. The influx of cold water into the Indian and Pacific Oceans must be in the former entirely, and in the latter very nearly so, from the Antarctic basin; but in the North Atlantic, at least, the cold bottom-water must be principally derived from the Arctic, while that in the South Atlantic flows in from the Antarctic. As we have already observed, this influx of cold water "creeping" along the bottom of the ocean from the poles to the equator, is due to the unequal densities of polar and equatorial waters; but Sir Wyville Thomson thinks that "the influx of cold water into the Pacific and Atlantic Oceans from the southwards, is to be referred to the simplest and most obvious of all causes, the excess of evaporation over precipitation in the northern portion of the Land Hemisphere, and the excess of precipitation over evaporation in the middle and southern parts of the Water Hemisphere." But we have no *data* which warrants the supposition that precipitation exceeds evaporation in the Southern Hemisphere; and, generally speaking, the conditions which regulate precipitation and evaporation would incline us to believe that evaporation exceeds precipitation in the Water Hemisphere, and that precipitation exceeds evaporation in the Land Hemisphere.

Ocean-Currents.—Influence of the Earth's Rotation.

134. The student must bear in mind that the various movements of the ocean which we have described, operate on a globe not a moment at rest, but rotating on its axis at the rate of over 1,000 miles an hour at the equator. Looking

at the earth's axial rotation from west to east, and the deflection of the great equatorial currents to the west, a superficial observer would probably conclude that the latter are simply the results of the former. The earth's rotation, however, is not the cause of either marine or aerial currents, but simply modifies their direction, deflecting them from right to left in the Northern Hemisphere, and from left to right in the Southern. Now, the axial motion decreases from 1,000 miles an hour at the equator, or 500 miles under the 60th parallel—to nothing at the poles. If the earth were at rest, a current flowing from either pole towards the equator would proceed in a direct meridional direction. But it is not so, and as the higher latitudes have a less axial velocity, the velocity proper to high latitudes is less than that proper to low latitudes ; or in other words—a current starting with a low velocity from either pole towards the equator, cannot at once acquire the velocity proper to the lower latitudes which it traverses, and, consequently, falls behind, as it were, to the west. A striking example of this is the Arctic current flowing into the Atlantic. The two branches of this current combine off Cape Farewell, and the current gradually moves into latitudes having a higher axial motion, and is deflected to the west.

135. But a current flowing from the equator to either pole advances gradually into regions having a less velocity of rotation ;—the result is, that instead of falling *behind* the meridian, its higher initial velocity is so much greater than that proper to the higher latitude, that it advances *before* the meridian, and thus is deflected to the east. Currents generated in north tropical seas are generally deflected to the east—*e.g.*, the Gulf Stream and the Japanese current—while those from the polar seas incline to the west ; and thus the currents which impinge on the western coasts of both the Old and New Worlds are *warm*, while those which flow towards the eastern coasts are *cold*. Hence the average temperature of maritime countries on the western coasts of the continents

is higher than that of other countries in the same latitudes on the eastern coasts. Thus the British seas and inlets are perfectly open all the year round, while on the opposite coasts of North America the St. Lawrence is ice-bound during the winter.

Ocean-Currents.—Temperature and Velocity.

136. The great distinction between currents and the other movements of the sea is—that the former alone effect an actual transference of the water from one part of the ocean to another. Both wind-waves and tides are mere undulations, leaving the water, as regards temperature, almost exactly the same. Ocean-currents, on the contrary, are the chief agents in the distribution of solar heat. Surface currents convey the heated waters of the tropics north and south to temper the rigorous cold of remote polar regions; while the iceberg-laden polar currents, and icy-cold underflow, moderate the otherwise unbearable heat of the tropics. The *temperature* of currents, therefore, depends primarily on their origin. Thus the Peruvian current, derived from the Antarctic drift, is 47° F. colder than the overlying air, and 10° F. colder than the adjacent open sea; while the equatorial current in the Atlantic has an average temperature of 75° F., or 6° above the water on either side. The Gulf Stream, as it leaves the Narrows, has a temperature of 80° F.; and in mid-ocean, before its final dispersion, it is still 8° or 10° higher than the adjoining water; while in winter, off Newfoundland, it is as much as 30° F. higher than the water through which it flows.

137. The *velocity* of ocean currents depends on several conditions, being modified by the configuration of the coast and depth of the water. The velocity of some currents decrease rapidly; others gradually flow faster. Thus the Gulf Stream rushes through the Straits of Florida at the rate of 4 miles an hour; but its velocity gradually decreases, being off Cape Hatteras 3 miles, and off Newfoundland 1½ miles an hour,

gradually merging into the slow north-easterly drift of the Atlantic of 5 miles a day. In the Pacific, on the contrary, the Japanese current, with a velocity of only 10 miles a day off Formosa, flows past the southern coasts of Japan at the rate of 50 miles a day. The great equatorial currents flow at the rate of 20 to 30 miles a day in the Atlantic, 15 to 24 miles in the Pacific, and 15 to 50 miles in the Indian Ocean. Currents generally attain their maximum velocity when passing through narrow channels,—*e.g.*, the Gulf Stream at the Narrows—or when rounding the extremities of continents, *e.g.*, Cape Horn current, Agulhas current, &c. Generally speaking, warm currents flow much faster than cold ones ; thus both the Arctic and Antarctic currents are very slow, scarcely exceeding 15 miles a day, while the Gulf Stream and other warm currents sweep on at a rate of 50, or even 100, miles a day.

X.

INFLUENCE OF THE SEA ON THE DISTRIBUTION OF CLIMATE.

138. Water, of all known substances, has the highest specific heat, or, in other words, has the greatest capacity for heat; that is, it requires more heat to raise the temperature of a given quantity of water to a certain degree than it does to raise the temperature of equal quantities of any other substance to the same degree. For instance, taking the specific heat of water as 1, that of mercury is 0.0333, so that 30 times as much heat would be required to raise the temperature of a given quantity of water as of an equal quantity of mercury.[1] Again, the heat required to raise the temperature of one pound of water one degree, would raise to the same degree four pounds of chalk or nine pounds of iron. As water, then, requires more heat to raise its temperature than any other substance, so much the more heat is liberated when its temperature is reduced. A reduction of one degree in the temperature of a given quantity of water, would effect the liberation of four times as much heat as a similar reduction of the temperature of an equal quantity of chalk, or nine times that of an equal quantity of iron. The earth's outer crust is composed of materials widely different as regards their capacity for heat; but, generally speaking, it requires four times as much heat to raise the temperature of water as it does that of land to the same degree. Land, therefore, is heated and cooled much more rapidly than water. Land and water absorb solar

[1] Tyndall. *(Heat as a Mode of Motion).*

heat differently; thus, while the heat falling on the land is communicated by *conduction*, that falling on water is distributed by *convection*,—that is, on land the *same* particles are exposed to the sun's heat, while at sea the surface particles first heated are displaced by colder particles from below, which are in turn heated and similarly displaced. It follows, then, that the heat gained by the land during the day is conducted downwards very slowly, inasmuch as its particles are, generally speaking, immovable. The particles of water, on the contrary, are incessantly in motion, and thus the heat gained is widely diffused. The heat falling on the land consequently accumulates on the surface, while that falling on the ocean penetrates to a considerable depth. Where the surface of the land is sandy and barren, the heat accumulates more rapidly than where it is covered with vegetation. But whatever the nature of the soil, the conductivity of its particles is so limited that the solar heat penetrates to the depth of scarcely four feet. Given the same initial temperature, the land will be more quickly heated than the sea; but while the heat of the former is soon dissipated, that of the water is retained for some considerable time.[1]

139. The difference between the temperature of the land and the sea during the day and night, is the cause of the well known *land and sea breezes*, common in all the warmer maritime countries, and a most important element in the climate of the tropics. During the day the temperature of the land, and, consequently, that of the overlying air also, is *above* that of the sea and superincumbent air. The air over the land, being heated, expands and ascends, and is replaced by a current of cooler air from the sea,—that is, a "sea-breeze." During the night, on the contrary, the temperature of the land and that of the air over it is quickly reduced below that of the sea, con-

[1] The mutual action of the heat of the land and water is not, of course, exerted directly, but indirectly, through the medium of the atmosphere. Air rapidly acquires the temperature of the surface which it overlies, and, being set in motion as wind, transfers the heat of the sea to the land, or *vice-versa*.

sequently the air over the sea rises, and is replaced by a current which sets in from the land,—that is, a "land-breeze."

140. The surface of the land, according to its position, nature of soil, elevation, &c., varies exceedingly as regards heat, one part being constantly parched under a fiery sun, while another is mantled with perpetual snow. The sea, on the contrary, has, on the whole, a more even climate; its vast thermal currents pouring the heated tropical waters into remote colder areas; while the icy-cold water of the poles, creeping as a vast under-current towards the equator, limits the warm layer of the tropics to a few hundred fathoms. Land and sea breezes illustrate on a small scale the mutual reaction of the unequal distribution of heat on sea and land. There is, as we have seen, a difference in the day and night temperatures of the sea and land sufficient to originate land and sea breezes. But the difference in summer and winter is still more marked. On land, in summer, more heat is gained in the long day than is lost in the short night; but in winter more heat is lost in the long night than is gained in the short day. Hence the heat of summer, and the cold of winter. The ocean, in summer, does not absorb the heat so rapidly as the land; but in winter it does not part with it so readily. Hence its comparative coolness in summer, and warmth in winter. The influence of air-currents from the sea to the land, and *vice versa*, is thus easily explained. In summer, winds from the sea *cool*, and in winter, *warm* the land. This being the case, the climate of those countries bordering on the sea will be more equable than those removed from its influences. In the former the heat of summer will be tempered, and the cold of winter moderated, by the winds sweeping over them from the sea; but in the latter, the heat of summer and cold of winter will be excessive.

141. The most important agents in the distribution of heat are marine and aerial currents. The former only are properly within the scope of this work, and we must therefore refer the

student desirous of investigating the climatical influence of the latter to other works on Physical Geography, in which the subject is fully discussed.[1] That the great ocean currents do exert a perceptible influence on the climate of countries towards which they flow is evident. Take the North Atlantic, for instance. Its *eastern* shores are bathed in warm water, most probably the prolongation of the Gulf Stream. The result is that, during the severest winters, the British seas are perfectly open, and the whole coast to Norway is clad with a luxuriant vegetation. Its *western* shores are washed by the cold, iceberg-laden Arctic current—with the result that, during the winter, the ports north of Halifax are ice-bound; and the cold, sterile coasts of Labrador and Newfoundland contrast strangely with the north of France and the Emerald Isle. One might bathe off the North Cape of Norway, in 71° N. lat., in water as warm as that in the harbour of New York, on the opposite side of the Atlantic, in 40° N. lat., two thousand miles further south.[2] Geikie remarks that the harbour of St. John's, Newfoundland, although two degrees further south than Liverpool, has been frozen over in June.

142. The Japan current and westerly drift towards the western shores of North America, are, in the Pacific, what the Gulf Stream and north-easterly drift are in the Atlantic. While the Columbian and Californian coasts are always open, the Sea of Okhotsk is frozen over during the winter months.

143. Whether the winds or ocean currents are the more important agents in the distribution of heat, is as yet a moot point; but the climatical influence of currents alone must be very great. The heat conveyed into the North Atlantic by the Gulf Stream has been estimated at one-fourth the total

[1] The climatical influence of air-currents, and other relative subjects, are admirably discussed in Professor Hughes's *Class-Book of Physical Geography*, of which a new and enlarged edition has recently been published by Messrs. George Philip & Son.

[2] Keith Johnston.

solar heat received by that ocean. The stoppage of this current alone would cause a loss of one-fourth the heat which renders North-western Europe habitable. Were the Gulf Stream stopped, icy-cold currents from the Arctic would sweep past Norway, and, enveloping the British Isles in their chilly grasp, would cumber our coasts with ice even in summer. The Black current of the Pacific is almost as important as the Gulf Stream. Thermal currents also set southward along the eastern shores of South America and South Africa, but these are inferior in size and as heat distributors compared with the vast northerly currents. The additional heat conveyed by the latter results in the Northern Hemisphere having a higher mean temperature than the Southern. These conditions point to the enormous climatical influence of thermal oceanic currents. Owing to the earth's spherical form, a superabundance of heat is received at the equator; whilst in high latitudes far too little is received to make the earth habitable for mankind. Oceanic currents, as we have seen, modify this state of things, by transferring heat from the Torrid Zone to the Temperate and Frigid Zones. "*Stop the oceanic currents, and the world is, in high regions, uninhabitable.*"

144. The difference as regards heat, owing to the proximity of the sea, affords us a basis for a classification of climates. The equable climates of countries near the sea directly subject to its beneficent influence may be called *maritime* or *insular;* while the excessive heat and intense cold of inland countries are the characteristics of an *extreme* or *continental climate.* The climatical influence of the sea is perhaps most strikingly shown by contrasting the average temperatures of maritime and inland countries in the same latitude. Edinburgh and Moscow have nearly the same latitude: but while the average summer and winter temperatures of the former is 57° and 38°, those of the latter are 64° and 15° respectively—thus showing a mean annual range at Edinburgh of only 19°, but at Moscow

of 49°. The excessive heat, and still more intense cold, of Central Asia, prove indirectly the indissoluble connexion between equability of temperature and proximity to the sea. Huc tells us that "in the deserts of Tartary, and especially in the country of the Khalkas, the cold is so terrible, that during a great part of the winter the mercury freezes in the thermometer; and often when the earth is covered with snow, and the north-west wind begins to blow, it drives the avalanche before it, till the whole plain looks like a white stormy ocean."

145. The most perfect examples of insular climates are to be found among the islands of the South Sea, the range in many groups scarcely exceeding five or six degrees throughout the year.[1] New Zealand and Tasmania, in the Southern Hemisphere, and Great Britain, in the Northern, have comparatively uniform temperature—varying only 20° on an average in the year. As an example of a strictly continental climate, we may take Central Asia, where—in the same latitude as Great Britain—the winter temperature sinks 32° below freezing point, rising in summer to 70°, the range being thus fully 70°. But even this is exceeded, for at Yakutsk, in Siberia, the winter temperature is −40°, while that of the summer is 62°; the range thus amounting to 102°. The influence of the sea in the distribution of climate is graphically shown at a glance in charts of isothermal lines, the diffused warmth of the thermal currents bending the lines towards the poles, while the cold polar streams deflect them towards the equator.[2]

---

[1] The most perfect case is the Friendly Islands, where the difference is only 2°.—*(Skertchley.)*

[2] Charts showing the isotherms of (1) mean annual temperature, (2) mean summer temperature, (3) mean winter temperature, and (4) distribution of rain, &c., are given in *The Atlas of Physical Geography*. (George Philip & Son)

XI.

ACTION OF THE SEA ON THE EARTH'S CRUST.

146. Of the thousands of earnest students of the physical geography of the globe, but very few have the time or the means to become actually acquainted with the various phenomena, the origin and functions of which they endeavour to trace. Few are privileged to climb the snow-capped heights of Asia or America; or to gaze in mingled amazement and admiration at the thundering fall of a mighty cataract; or to witness the awe-inspiring sight of a great storm at sea, watching with beating heart the vast billows, driven before the wind, and breaking with a deafening roar on a rock-bound coast. By far the larger number of students can never hope to *see* these and other grand displays in the wonderful panorama of nature, but, fortunately, actual *sight*, though a most useful adjunct, is not absolutely necessary to a thorough *knowledge*. Humboldt, in his Kosmos, truly says, that "every little nook and shaded corner is but a reflection of the whole of nature." Carl Ritter amplifies the thought, and remarks, that "*wherever our home is, there lie all the materials we need for the study of the entire globe.* The roaring mountain-brook is the type of the thundering cataract; the geological formations of a single little island suggest the broken coast-line of a continent; the study of the boulders which are so thickly scattered, in token of a great primeval deluge from the north, reveals the structure of whole mountain-chains. A small range of hills may be taken as the type of the loftiest Cordillera."[1] From these and other considerations, Ritter

[1] *Comparative Geography* (Ritter).

concludes that a thorough study of the district where we live is the true key to the understanding of the geography of foreign lands, for the eye may be easily trained to see the greater in the less. Applying the foregoing considerations to the special subject of this work—the geography of the ocean—it will be evident that comparatively few students will be so circumstanced as to be able to verify the facts given by sight. But those who do not live at the seaside may form true ideas of the forms and phenomena described, by a careful study of their own district, accompanied by a few simple practical experiments, illustrating such points as Nature of Wave-motion,[1] Oceanic Circulation,[2] and so on.

147. The work of the rain and rivers[3] may be practically studied almost everywhere. The gradual wearing away of the superficial strata of the land by aqueous agency is a familiar subject. The rounded pebbles, gravel, and sand found in the bed of a stream, are not only the evidences, but the actual agents of the action of the water. A pond or lake formed by the expansion of a stream, and temporarily retaining its waters, may be regarded, in many respects, as a miniature of that vastly greater receptacle of all the running waters of the globe,—the ocean. Of the sediment discharged into the lake by the stream, the heavier particles fall to the bottom first; the finer *detritus* is carried further away, but, also, ultimately settles down. And the same in the sea. Of the sedimentary matters brought down by rivers, or directly removed by the waves, the coarser particles subside first, while the finer sand and mud are transported to considerable distances by tidal-waves and currents, but are, also, finally deposited on the ocean-floor.

148. That the greater may be seen in the infinitely less, will be evident from the fact that the action of the sea on

---

[1] Art. 109. [2] Art. 127.

[3] The student should consult Huxley's *Physiography* (Macmillan & Co.) for full information on this point.

the earth's crust in its threefold aspect—(1) *destructive*, (2) *reproductive*, (3) *preservative*—may be exemplified, to a certain extent, by a very simple experiment. For if a small pool be formed where the bank of a stream is moderately level, and then connected with the stream by a miniature canal, having a slight slope, it will be seen that the looser particles in the bed of the little channel are swept down by the water into the pool, where, the water being perfectly quiet, they fall to the bottom. Now, so long as the water in the pool is at rest, its action is evidently limited to the reception and deposition of the sediment discharged into it by the stream. But if its surface be disturbed—either artificially or naturally—by a current of air, the waves thus formed will, as they break on the banks, be seen to dislodge first the finer and then the coarser particles, which are gradually spread evenly over the bottom,—the coarser close to the bank, while the finer mud settles down further from it. If the air current acting on the water be strong and continuous, a breach may be made in the opposite bank, through which the water will make its escape. Or if a few miniature cliffs be formed at the water's edge, the continuous action of the wavelets at their bases will be seen to result in the formation of little caves or arches, gradually penetrating inwards, until at last one and another are undermined to such an extent that they topple over into the water, forming a line of rubbish along the shore, or here and there forming little low promontories jutting out into the water. In the latter case, if the artificial air current be directed to force the water against one side of a promontory, it will probably in a short time result in a gradually widening channel being cut across, and thus the projecting part will be transformed into an island. On close examination of our miniature sea, it will most probably be found that its beach or shore line is not "wasted" everywhere alike,—some parts being rapidly penetrated, in others the erosion being scarcely perceptible, while

at a few points, instead of being wasted, the land actually encroaches on the water—that is, some of the sand and mud displaced elsewhere, instead of being deposited on the bottom, is thrown ashore again, thus not only *preserving* the beach at those particular points, but actually *reproducing* new land. Or some of the heaped-up *detritus* might be just covered with water, thus forming a shoal or sandbank. And if, after a time, the supply of water be stopped, and the pool drained, the various changes due to the action of the water would be still more apparent. The new strata formed on the bottom would be easily seen by making a careful cutting, and removing the earth on one side. Of course it is only possible on such a small scale to employ two agents, viz.—waves, and a trifling surface drift or current produced by an artificial air-current. But in the ocean, the action of tide-waves and deep-sea currents is added to that of wind-waves and surface drifts. These, however, introduce no new aspect, and our little pool and streamlet thus serve to illustrate the action of rivers and the sea on the land.

149. We have thus exemplified in miniature (1) the *destructive* action of the waves, which are the great agents of marine denudation; (2) the *reproductive* action of surface movements of the water—throwing up again on one part of the coast the *débris* removed from another; and (3) the *preservative* action of the great mass of the water—preserving the newly-deposited sediment on the bottom from being wasted or even disturbed. The superficial stratum of the sea only is engaged in wasting or directly adding to the shore; but the great mass of the ocean overlies constantly-increasing deposits, which may in time be upheaved, and, being acted on by all the atmospheric and aqueous agencies [1] now at work in

[1] Other "agents of change" are continually in operation, such as the gradual upheaval and subsidence of the land, volcanic forces, &c. The continual change which the surface of the earth undergoes is fully and most clearly described in Hughes's *Physical Geography* (pp. 196-297), published by Messrs. George Philip & Son.

levelling the present land, may eventually become habitable. It may therefore be truly said that the present ocean is but a vast workshop, where the materials of future continents are elaborated and preserved.

The Sea as an Agent of Destruction.

150. Just as the wavelets in our miniature sea "wasted" the beach here, and added to it there; undermined a cliff at one point, and formed an island at another; so also the waves of the Ocean incessantly dash on the exposed margin of the land, rapidly disintegrating the softer materials, and surely, although much more slowly, wasting away the hardest rocks. The peculiar grating sound which always accompanies the advance and retreat of the waves on a shingly shore, plainly indicates the incessant "planing," as it were, of the land, more especially that portion between high and low-water mark. The rounded pebbles are mute, but at the same time most expressive, evidences of continual attrition—of being dragged up and down the beach, rubbed against one another—until their angularities have entirely disappeared. Being almost constantly in motion, the pebbles are reduced to coarse gravel, then into sand, and lastly into fine mud, which, easily held in suspension for a considerable time, is removed by tidal waves and currents, but finally also settles down on the floor of the ocean.

151. We have already (Art. 112) noticed the great force of waves. Such indeed is their power, that immense blocks have been displaced, lighthouses swept away, and breakwaters broken down. The pressure of the Atlantic breakers on the coasts of the Western Hebrides has been experimentally proved to be, on an average, 611 lbs. per square foot in summer, and 2,086 lbs. in winter.[1] The spray has been occasionally driven right over the lantern of the Bell Rock Lighthouse, 112 feet high, and even over that of the Eddystone Light-

[1] Mr. Stevenson.

house, 140 feet high. Skertchley mentions that the lantern at Dunnet Head, 270 feet above the level of the sea, has been cracked by pebbles hurled from the beach by the waves ; and that during very violent storms, the Atlantic waves rush up the sides of the cliff at Hoy Head, in Orkney, to a height of nearly 600 feet. The pressure on the more exposed parts during violent storms must therefore be from 6,000 to 8,000 lbs. per square foot ! This fact alone would suffice to prove the tremendous power of waves, and the destructiveness of their action, not only on the softer, but also on the most rocky, coast exposed to their fury.

152. But it must be remembered that the denuding power of waves does not lie simply in their weight or force of impact, but also in the use they make of the loose pebbles and fragments of stones strewn on the beach. These are swept upwards by the advancing wave, and dashed against the cliffs, broken in pieces themselves, but also breaking down or further weakening some part of the rock. Wave after wave, similarly charged, dash on and hurl their missiles against the cliff, which is thus constantly battered, and ultimately undermined; huge fragments are loosened, and fall into the sea. And since the hardest and most rocky coasts thus suffer, it will be evident that the softer cliffs and beaches will be loosened and demolished much more rapidly ; and, where the coast is formed of materials of unequal hardness, the softer portions are swept away, leaving the harder rocks partially detached or quite isolated. The characteristic irregularity of contour of the land-masses is thus a result of the unequal hardness of the strata exposed to the action of the sea. The harder coasts are bold and irregular, while the softer portions are regularly carved out into bays and coves. The limits of this little work, however, prevents us from following out this part of our subject fully : we must therefore restrict ourselves to a brief statement of the principal instances of the changes, due to the action of the sea, on our own and other coasts.

MARINE DENUDATION—INSTANCES ON BRITISH AND OTHER COASTS.

153. Geologically considered, the oldest rocks in Britain lie along its western and northern shores; while the newer, and therefore softer, strata are in general limited to its eastern and southern districts. The sea-cliffs on the southern and eastern coasts of England are largely composed of chalk, soft sand, or clays, and are therefore more subject to the erosive action of the sea than the older and harder rocks on the west coast. This, as Huxley points out, is strikingly shown in the configuration of the east and west coasts respectively. The sites of some of the former seaports of Yorkshire are now about a mile from the present shore, and the site of Old Cromer is now entirely covered by the waters of the German Ocean. Several other well-known villages of former days on the coast of Norfolk and Suffolk have disappeared; "manors and large portions of neighbouring parishes have been swallowed up, piece by piece; nor has there been any interruption, from time immemorial, in the ravages of the sea."[1] In the Isle of Sheppey, at a spot where the cliffs are from 60 to 80 feet high, fifty acres have been lost in twenty years.[2] The church at Reculver,[3] in Kent, was, three centuries ago, nearly a mile from the sea; now the towers alone remain, and these are preserved only by means of an artificial causeway on the beach.

154. The opposite shores of the German Ocean bear witness to the same destructive activity of the sea. The tract now covered by the Zuyder Zee was, until the 13th century, dry land, with the exception of a small depression filled by the waters of Lake Flevo. Since then the sea has, again and again, inundated large tracts, overwhelming towns and villages; and were it not for the natural sand-dunes and artificial dykes, the sea and rivers would inundate the greater part of the Nether-

[1] Hughes. [2] Sir Charles Lyell *(Principles of Geology.)*
[3] The site of the Roman military station of *Regulbium.*

lands. The Texel, and other islands to the north of Holland, and, still more, Heligoland, have been gradually reduced and altered. The latter was at one time connected with Sandy Island, now many miles distant. In 1825, the narrow strip of land that separated the Lym Fiord in Denmark from the North Sea was cut through during a violent storm; but the channel thus formed, though still open, is not adapted for commercial purposes. The Channel Islands and the neighbouring French coast appear also to have been denuded to some extent, there being at the present time 20 feet of water over what was once dry land. [1]

The Sea as a Reproductive and Preservative Agent.

155. Besides being an agent of destruction, the sea is also an agent of reproduction—directly engaged in forming new land, which may in time be reclaimed and cultivated. The material removed from one part is sometimes partly thrown ashore again on the adjacent coast, and thus the land may actually encroach on the sea. We have an instance of this on the shores of Lincolnshire, where large tracts formerly covered by water have been reclaimed. In several other places the land is protected from the sea by deltas and bars, formed from the accumulated *débris* brought down by large rivers, such as those of the Mississippi, the Nile, the Ganges, and others.

156. The sea, by means of its waves and currents, acts generally on a limited portion of the land only—viz., that between the high and low-water mark. During violent storms its action may extend as high as 200 or 300 feet or more above the sea level, and downwards to a corresponding depth. Its action between these limits is of course greatly assisted by atmospheric agencies—such as the winds, chemical action of the air, rain, &c. These, however, cannot be properly treated of in a work devoted exclusively to the ocean; but most works

[1] Proceedings of the Royal Geographical Society, vol. x.

on physiography, or physical geography, contain a more or less full account of their action. Suffice it for us now to state that all the various agents of denudation are unceasingly in operation; and of the resulting *débris* carried into the sea, the coarser *detritus* falls to the bottom close to the shore, while the finer particles are swept out into the open sea, but finally also settle down on the floor of the ocean. But the sea itself teems with various forms of animal and vegetable life—the larger and higher organisms inhabiting the surface stratum, while at great depths myriads of the *foraminifera* and other minute forms abound; so that, amongst the sedimentary matters eroded from the land, there are deposited on the ocean floor enormous quantities of the remains of marine forms, which must in time be deeply imbedded in the new strata thus formed. The present dry land is, as is well known, formed of rocks, in many of which fossilized remains of marine animals are frequently found. What is now land, therefore, must at one time have been covered by the sea, otherwise the remains of marine animals could not have been thus imbedded. In fact, the whole series of stratified rocks must have been laid under water, in exactly the same manner that the *débris* of the land is now deposited on the floor of the ocean.

157. The mechanical action of the largest waves ceases at a depth of 100 fathoms, and even the motion of the deeper submarine currents is scarcely perceptible, so that the greater part of the bed of the ocean is covered by a cushion of water, nearly if not absolutely still—incapable, indeed, of disturbing the fleecy-like deposits of tiny shells and other matters that cover so large a part of the ocean floor. The sea is, therefore, eminently *preservative*, its all but absolute repose at great depths permitting the uninterrupted and even deposition of the materials of future continents. And if we may judge of the future by the past, the various agents of change—igneous, aqueous, and atmospheric—must ultimately alter the present

distribution of land and water, and what is now dry land may again be covered by the sea, and the present ocean floor may be upheaved, and become habitable. But the process is slow—so slow, indeed, that the six thousand years of history are as nothing compared with the vast periods which must elapse before a radical change can be effected by *natural* agencies. Professor Huxley has estimated that a million years must elapse before the basin of the Thames will be worn down to the sea-level; while the reduction of the British Isles to a flat plane at sea-level would occupy about five and a-half million years![1]

---

[1] "On Modern Denudation."—(*Geikie.*

PART III.

THE GEOGRAPHY OF PARTICULAR OCEANS.

I.—The Atlantic Ocean.
II.—The Pacific Ocean.
III.—The Indian Ocean.
IV.—The Antarctic Ocean.
V.—The Arctic Ocean.

George Philip & Son, London & Liverpool.

III.

THE GEOGRAPHY OF PARTICULAR OCEANS.

I.

THE ATLANTIC OCEAN.

The Atlantic—its Boundaries and Extent.

158. The Atlantic Ocean, though considerably smaller than the Pacific, is by far the more important, and, having been for centuries the great highway of commerce between the more civilized nations of the earth, it is also much better known. Bounded on the east by the Old World, and on the west by the New World, its huge, trough-like basin extends from the Arctic Circle on the north to the Antarctic Circle on the south, somewhat in the shape of the letter S; and as the projections on the one side correspond generally to the indentations on the other side, the opposite shores of the Atlantic preserve a remarkable parallelism, not inaptly shown by the name occasionally given to it—namely, the "Atlantic Canal." The coast-line of this ocean is rendered so irregular by the numerous seas, bays, gulfs, and other inlets, that the student will obtain a better idea of its configuration by a careful examination of the accompanying map, than by any merely verbal description, however full and accurate. Besides its comparative narrowness and irregularity of outline, and consequent enormous extent of coastline—greater, indeed, than that of all the other oceans taken together—the distinguishing features of the Atlantic Ocean are its comparatively few islands; the greater irregularity of coastline and number of

islands in its northern than in its southern division; the magnitude, regularity, and velocity of its currents; its Sargasso Sea, round which, in an endless cycle, the great Equatorial current, the Gulf Stream, and African current flow; the frequency and violence of the gales which sweep over it, rendering it the stormiest and most dangerous to navigation of all the great oceans; its great variety of temperature, extending from the frozen basin of the Arctic, through the tropics, to the ice-bound Antarctic Ocean; its enormous climatical influence, directly affecting a drainage area of nearly 20,000,000 square miles; its position as the great commercial highway of the more civilized nations of the world, and, consequently, its intimate connection with the promotion and diffusion of an advanced civilization.

159. As a glance at the map will show, both sides of the "Atlantic Canal" preserve a generally north-east to south-west direction from the Arctic Circle to the Tropic of Cancer; thence to Cape St. Roque on the American, and the mouth of the Congo, or Livingstone River, on the African, coast, the general trend of both sides is in an exactly opposite direction —namely, from north-west to south-east. Thus far the general parallelism of the opposite shores is remarkably maintained; but farther south the African coast trends nearly due south, while the South American coast diverges to the south-west. But while the former terminates in Cape Agulhas (34° 49′ S. lat.), the latter extends 20° further south to Cape Horn. *Theoretically*, the waters of the Atlantic south of Cape Agulhas are divided from those of the contiguous Indian Ocean by an imaginary line drawn along the 20th meridian from that cape to the Antarctic Circle; on the west, the limiting line between the Atlantic and Pacific Oceans south of Cape Horn extends meridionally from that cape to Graham Land. The following table, showing the countries of the same latitude on the opposite sides of the Atlantic, may be of service to the student, if carefully read over and compared with the map:—

Western Shores.			Eastern Shores.	
North America.	Greenland	opposite to	Norway and Sweden.	Europe.
	Labrador		Denmark.	
			British Isles.	
			Holland and Belgium.	
	Canada Proper, with Newfoundland, New Brunswick, C. Breton, Nova Scotia, ...	„ „	France.	
	United States	„ „	Spain and Portugal.	
			Morocco, and W. African Coast as far as C. Bojador.	Africa.
	Mexico, West Indies, Central America	„ „	W. African Coast from C. Bojador to mouth of R. Grande in Senegambia.	
South America.	Venezuela	„ „	S. part of Senegambia, Sierra Leone, Liberia, Guinea (Ivory Coast, Gold Coast, &c.)	
	Guiana			
	Brazil	„ „	W. African Coast S. of Cameroon R. mouth, including Loango, Congo, Angola, Benguela, Ovampo, Damaraland, Namaqualand, and N. part of C. Colony.	
	Uruguay	„ „	Southern part of C. Colony.	
	Buenos Ayres	„ „		
	Patagonia.....	„ „		

161. The *area* of the Atlantic has been variously estimated at from 25 to 35 millions of square miles. One high authority [1] gives 35,160,000 square miles as the superficial extent of this ocean, which thus occupies nearly a fifth part of the entire surface of the earth. While its *length* is upwards of 9,000 miles, its *breadth* varies from 900 miles between Norway and Greenland, to upwards of 5,000 miles between Cape Blanco and Mexico. Between Portugal and the United States the distance is scarcely 3,400 miles, further diminished between Ireland and Labrador to 2,000 miles. Under the equator the width is not less than 4,200 miles, but between Sierra Leone and Brazil it is only 1,700 miles. Southward it gradually widens, until the Cape of Good Hope and the opposite coasts of La Plata are over 4,000 miles apart.

The Atlantic—its Islands.

162. The principal islands in the North Atlantic are—*Great Britain* and *Ireland*, with the *Hebrides*, *Orkneys*, *Shetlands*, and other contiguous islands; the *Faroe Is.*, the *Vigten*, and other islands off the coast of Norway; a chain of islands along the western coasts of Denmark and Holland; and the *Channel Islands*, off the northern coast of France. Off the West African coast, north of the equator, we have *Madeira*, the *Canary* and *Cape Verd Islands;* and further out, in the open ocean, the *Azores* or Western Isles. In the Gulf of Guinea are the three small islands of *Fernando Po*, *Princes Island*, and *St. Thomas*.

163. With the exception of the *Bermudas*, the islands belonging to North America are arranged in two distinct groups—*Newfoundland*, *Anticosti*, *Cape Breton*, and *Prince Edward's Island*, off Canada; and the West India Islands, extending from Florida to the mouth of the Orinoco. The West India Islands are broadly divided into the Greater and Lesser Antilles. Of the Greater Antilles, the principal are *Cuba*, *Haiti*

[1] Dr. Keith Johnston.

or *San Domingo*, *Porto Rico*, and *Jamaica*. The *Bahamas* skirt the Atlantic side of the first two. The Lesser Antilles are further subdivided into the Leeward Islands *(Santa Cruz, St. Kitts, Anguilla, Guadaloupe, Dominica,* &c.); and the Windward Islands *(Martinique, St. Lucia, St. Vincent, Barbados, Grenada, Tobago, Trinidad,* &c.) Along the northern coasts of South America are the Leeward Islands proper *(Oruba, Curaçao, Buen Ayre,* and *Margarita).* The only other considerable islands are *Southampton* and *Mansell Islands*, in Hudson Bay.

164. THE SOUTH ATLANTIC OCEAN is remarkably free from islands. Along the West African coast, from the equator to Cape Agulhas, there are none of any size or importance, the principal islets being *Annobon*, off Cape Lopez; *Ichaboe* and *Possession Island*, off the Namaqua coast; and *Dassen* and *Robben Islands*, not far from Cape Town. In the open ocean we have the rocky islands of *Ascension, St. Helena, Tristan d'Acunha, Gough,* and *Bouvet*—evidently the culminating points of the submarine range that divides the basin of the South Atlantic. The opposite shores of South America are also almost destitute of islands, there being none worth noticing from Cape St. Roque to Magellan Strait. Off the latter lie the *Falkland Islands*, and further east, *Georgia Island.* The southern extremity of South America is a cluster of islands, collectively called *Tierra del Fuego.* In the open ocean, eastward, are the *Sandwich Islands, South Orkneys,* and *South Shetlands.*

THE ATLANTIC—ITS SEAS, BAYS, AND GULFS.

165. The coast-line of the Atlantic Ocean is so extended by numerous indentations, as to exceed in length that of all the other oceans taken together. Nearly all its inland gulfs and bays, however, belong to its northern division—the North Atlantic, which includes the vast expanse between the equator and the Arctic Circle. The principal branches on its eastern side

are—the *Baltic Sea*, with the Gulfs of Finland, Bothnia, and Riga; the *North Sea* and the *English Channel*, separating Great Britain from the Continent; the *North Channel*, *Irish Sea*, and *St. George's Channel*, between Great Britain and Ireland; the *Bay of Biscay*, formed by the western coast of France and the northern coast of Spain; the *Mediterranean Sea*, between the south of Europe and North Africa, with the Gulf of Lyons, Adriatic and Ægean Seas, the Levant, and Gulfs of Sidra and Cabes; the *Black Sea*, connected with the Mediterranean by the Bosphorus, Sea of Marmora, and the Dardanelles. The only considerable indentation in the West African coast is the *Gulf of Guinea*, with the Bights of Benin and Biafra. Near the extremity of South Africa are the minor inlets of *Table Bay* and *False Bay*.

166. On the western side of the Atlantic we have *Hudson Bay*, with James Bay; the *Gulf of St. Lawrence*, with Chaleur Bay; the *Bay of Fundy; Chesapeake Bay; Gulf of Mexico*, with the Bay of Campeachy; the *Caribbean Sea*, with the Bay of Honduras, the Gulfs of Columbus, Darien, Venezuela with Lake Maracaybo, and Paria. Thence the coasts of South America are, on the whole, regular and unbroken, the only considerable indentations being the *Estuary of the Amazon*, the Rio de Para, the Bay of Bahia, the *Rio de la Plata*, and the Patagonian gulfs of S. Matias and S. George.

The Atlantic—Intercommunication by Straits and Channels.

167. The Atlantic communicates with the Arctic on the north by two unequal channels, between Norway and Iceland, and Iceland and Greenland respectively. The latter is termed the *East Greenland Channel*, or Denmark Strait; the former has no distinctive appellation. By the North Sea, the *Skager Rack*, the *Cattegat*, and *Great* and *Little Belt*, and the *Sound*, the Baltic is in communication with the Atlantic—either

north round Scotland, or south through the *Straits of Dover* and the *English Channel*. The Irish Sea similarly opens to the ocean on the north by the *North Channel*, and on the south by *St. George's Channel*. The *Bristol Channel* is virtually an extension of the estuary of the Severn. The Atlantic is connected with its most important inland sea, the Mediterranean, by the *Straits of Gibraltar*. The *Dardanelles*, Sea of Marmora, and the *Channel of Constantinople* connect the Mediterranean with the Black Sea, and the Suez Canal with the Red Sea. By the Mediterranean, Suez Canal, and Red Sea, vessels may now proceed *directly* from the Atlantic to the Indian Ocean without rounding the Cape of Good Hope.

168. On the western, or American side, *Davis Strait* opens into Baffin Bay, and thus by Smith Sound, Kennedy and Robeson Channels, into the "Palæocrystic Sea," north of Greenland. Hudson Bay is connected with the Atlantic by a strait of the same name, *Hudson Strait*. The Gulf of St. Lawrence admits the Arctic current on the north by the *Strait of Belle Isle*. *Northumberland Strait*, on the south, between Prince Edward Island and Nova Scotia, is connected with the open ocean by the narrow *Gut of Canso*, between the latter and Cape Breton. The Gulf of Mexico is connected with the Atlantic by the *Strait of Florida*, and with the Caribbean Sea by the *Channel of Yucatan*. The Caribbean Sea communicates with the open ocean by numerous channels between the West India Islands, the principal of which are the *Windward Pass*, between Cuba and Haiti; and the *Mona Pass*, between San Domingo and Porto Rico. The *Straits of Magellan*, and other channels between the island group of Tierra del Fuego, admits of communication with the Pacific Ocean without "rounding" Cape Horn.

169. The connection of the Atlantic with the other great oceans may be thus summarised:—with the *Arctic* by Hudson and Davis Straits, East Greenland Channel,[1] and the wide ex-

[1] Also called Denmark Strait.

panse between Iceland and Norway; to the *Antarctic* it opens broadly; contiguous with the *Indian Ocean* for two thousand miles south of Cape Agulhas, and also communicating with this ocean indirectly by the Mediterranean, Suez Canal, and Red Sea; with the *Pacific* through Magellan Strait and other Fuegean Channels, or round Cape Horn. Under very favourable circumstances vessels might reach the Pacific from the Atlantic by the North-West Passage through Baffin Bay, Barrow Strait, Melville Sound, Banks' Strait, the Arctic Ocean, and Behring's Strait, *or* through Ross and Simpson Strait, and thence west through Dease Strait and Coronation Gulf. The recent voyage of the "Vega" has proved the possibility of communication with the Pacific during the summer, by the North-East Passage round the northern coasts of Europe and Asia, and then through Behring's Strait. The proposed "Inter-oceanic Canal" will enable vessels to pass directly from the Atlantic to the Pacific, and thus obviate the necessity of rounding Cape Horn, or risk the dangers of a North-East or North-West passage—the former of which may be of some, but the latter can never be of any, commercial importance, both being ice-bound during the greater part of the year.

The Atlantic.—General Character of Coasts.

170.—The general character of the coasts of the Atlantic will probably be better understood if the coasts of *each* country bordering upon it be briefly described. Following the same arrangement as that in the table on page 121, we have first the coast of *Norway*, elevated and deeply indented by numerous inlets of generally deep water called "fiords," and also skirted by innumerable islets and rocks. The coast of *Sweden*, on the contrary, is low, and not so rugged. The Baltic shores of *Russia* are more broken, and present the large inlets of Finland and Riga. The South Baltic coast, belonging to *Germany*, is on the whole flat, and more or less indented.

A peculiar feature in this part of the coast is the occurrence of shallow lagoons or haffs, almost entirely enclosed by tongues of low land. The principal of these are the Curische Haff, into which the Niemen flows; the Frische Haff, receiving the Pregel; and the Gulf of Dantzic, receiving the Vistula. The Oder flows into the Stettiner Haff. The only other opening is the Bay of Lubec. The coast of *Denmark* is low, and considerably indented; the islands Zealand and Funen being scarcely less broken than the peninsula of Jutland, the northern part of which is now traversed by the Lym Fiord. [1] The coasts of *Holland* and *Belgium* are of the same level character, and are indeed in several places actually below sea-level, being protected from inundation by artificial dykes or natural sand-dunes. During violent storms, however, the sea has repeatedly burst through both natural and artificial embankments, and inundated large tracts. The Dollart Zee and Zuyder Zee were thus formed in 1277 and 1282. [2]

171. The western coasts of *Great Britain* are, generally speaking, more rugged and broken than the eastern. From Caithness to the Firth of Tay the coast is on the whole bold, and in some parts rocky; thence to Berwick is an alternation of rocky cliffs and low sandy beaches. Further south, to Flamborough Head, the shore cliffs are lower, and the outline is more regular. Thence to the chalk cliffs of Kent is a succession of chalk or clayey cliffs and low beaches. The south coast of *England* is on the whole flat, with a few stretches of chalk cliffs as far as Exmouth; thence to Land's End it is bolder, and more rocky. The west coast of England may be

[1] Before 1825 the western extremity of the Lym Fiord was separated from the North Sea by a narrow isthmus, but during a violent storm in that year the sea burst through the isthmus, and thus a continuous channel was formed from the North Sea to the Kattegat, which, had it been deep enough, would have enabled vessels to enter the Baltic without rounding the "Skaw."

[2] Butler, in "Hudibras," thus humorously describes the Netherlands: –

"A country that draws fifty feet of water,
In which men live as in the hold of Nature.
A land that rides at anchor, and is moor'd,
In which men do not live, but go aboard."

broadly divided into four sections :—Generally bold and rocky from Land's End to Hartland Point ; level around the Bristol Channel ; the Welsh coast moderately high and broken as far as Great Orme's Head ; again level to the Solway Firth, with the exception of a part of the coast of Cumberland. The whole of the west coast of *Scotland* is broken, and skirted with several large island-groups, and numerous islets and rocks. It is generally rugged and broken, and many of the "lochs" and "sounds" are extremely picturesque. The western and southern shores of *Ireland* are on the whole deeply indented, and in parts high ; but the eastern coast is generally level and unbroken, and destitute of good harbours.

172. The Bay of St. Malo is the only considerable inlet in the north coast of *France*, the west coast of which is more broken, and skirted by a few small islands. Generally high in Normandy and Brittany, south of the mouth of the Loire it assumes a level aspect, and is especially regular, low, and sandy from the mouth of the Gironde to Bayonne. [1] The Atlantic coasts of *Spain* and *Portugal* are remarkably bold and unbroken, and thus contrast strongly with those of the Scandinavian Peninsula. With the exception of the estuary of the Tagus, the Bay of Vigo, and Setubal Bay, scarcely any inlet in the north and west coast penetrates more than 10 miles inland ; while several of the fiords of Norway extend for more than 100 miles inland.

173. In striking contrast to the broken and irregular contour of Western Europe are the regular and unbroken coasts of Western Africa. From Tangier to Cape Nun the coast is bold and rocky. Further south the shores of *Senegambia* and *Guinea* are low, but generally fertile. The Bights of Benin and Biafra, and the Delta of the Niger, are marked by tropical swamps and jungles, the pestilential exhalations from which prove speedily fatal to Europeans. South of the equator

[1] This part of the coast borders on the "Landes," a barren, sandy tract, extending inland to the cultivated districts of Lot-et-Garonne.

the swamps and marshes give place to well-grassed plains and noble forests, with occasional cultivated tracts; but from Cape Negro to some distance south of the Orange River the shore is low, sandy, and barren. Thence to Cape Agulhas the coast is rugged and bold, the shore cliffs attaining in Table Mountain an elevation of nearly 4,000 feet above the sea.

174. The Atlantic shores of *North America*, though considerably indented, are yet inferior in extent to those of Western Europe. The shores of eastern *Greenland*, being constantly bathed by the cold Arctic current, are generally ice-bound. Its western shores are more broken, and somewhat higher. The coasts of the *Hudson Bay Territory* and *Labrador* are low, barren, and inhospitable, the few forts or villages being either Moravian Mission stations or depôts for furs. Passing the Gulf of St. Lawrence, which is ice-bound during the winter, the coast of the *United States* is on the whole level, and in some parts marshy. There are several good harbours, but the only large indentations from Nova Scotia to Florida are the Bays of Fundy, Delaware, and Chesapeake. The shores of the Gulf of *Mexico* are generally low and sandy, and off Texas fringed by long narrow islands, enclosing numerous lagoons. The delta of the Mississippi is flat and swampy, and yellow fever is prevalent at certain times of the year. The eastern coasts of *Central America* are in some parts low and sandy, but generally they slope more or less abruptly from the central mountain chain, which is continued along the Isthmus of Panama into the Andean system of South America. The coasts of *Venezuela*, *Guiana*, and *Brazil* are in general low and unbroken, but occasionally bold and rocky. There are several good harbours, but only two large indentations—the Gulf of Venezuela leading into Lake Maracaybo, and the Gulf of Paria. From the latter to Cape Corrientes the only considerable openings are the estuaries of the Amazon and the La Plata. The east coast of Patagonia is more broken, but there are scarcely any

good harbours. The shores of the island-group of *Tierra del Fuego* are generally bold and rugged.

175. Viewing the Atlantic as a whole, therefore, we find that its southern division is remarkably free from islands, and has a limited, because unindented, coast-line; while the North Atlantic contains several groups of large islands, and is so deeply indented by numerous bays, gulfs, and other inlets, that it has an enormously greater extent of coast. Of the four continental land-masses forming the eastern and western boundaries of the Atlantic, the shores of Europe and North America, but more especially the former, are the most irregular, and consequently the most extensive, while those of South America and Africa are remarkably regular and unbroken. On the whole, the irregularity and development of the Atlantic coast-line is such that it exceeds in length the total extent of the coasts of all the other oceans taken together.

The Atlantic—its River Systems.

176. We have already briefly enumerated the principal rivers flowing into the Atlantic, which receives several of the largest rivers of the globe. Although the Atlantic is scarcely half the size of the Pacific, yet its *drainage area* is 2¼ times greater, being 19,050,000 square miles, while that of the Pacific is only 8,460,000 square miles. The position of the Rocky Mountains and the Andes, and in a less marked manner the watersheds of Central Europe and Africa, determines the course of by far the larger number of the great rivers of the globe, either directly or indirectly, into the Atlantic. The Atlantic river-systems may be naturally divided into four sections, according to the continent over which they flow. A brief tabulated statement of the principal rivers can only be given here; the student will find full particulars in the "Geography of River-Systems."[1] In the following table

[1] Published by George Philip & Son. (Price 1s.)

those rivers which flow *directly* into the Atlantic are inserted —the others will be noticed in the description of the seas they flow into.

177. The Atlantic River Systems.

Section.	River.	Draining.	Length Miles.	Area of Basin. Sq miles
European Section.	Glommen	Norway	400	16,500
	Gota	Sweden	70	13,700
	Elbe	Germany	600	57,000
	Weser	„	380	17,800
	Rhine	Switzerland, Germany, & Holland	760	88,800
	Meuse	France, Belgium, & Holland	550	
	Scheldt	France, Belgium	250	8,700
	Seine	France	430	30,000
	Loire	„	570	48,000
	Garonne	„	350	33,000
	Minho	Spain	200	6,300
	Douro	Spain, Portugal	460	39,000
	Mondego	Portugal	120	2,700
	Tagus	Spain, Portugal	510	34,000
	Guadiana	„ „	450	26,000
	Guadalquivir	Spain	290	20,000
	Thames	England	215	6,160
	Severn	„	240	5,540
	Humber (Ouse, Trent)	„ „	150 180	9,950
	Mersey	„	70	1,748
	Tweed	Scotland	96	1,870
	Tay	„	100	2,400
	Clyde	„	98	1,580
	Shannon	Ireland	224	7,000
African Section.	Senegal	W. Africa	900	80,000
	Gambia	„	650	30,000
	Niger	C. Africa	2300	—
	Congo	„	2900	—
	Orange	S. Africa	1000	300,000

Section.	River.	Draining.	Length Miles.	Area of Basin. Sq. miles.
North American Section.	Mississippi, by main stream	United States	2400	1,300,000
	By Missouri	"	4000	
	St. Lawrence	Canada	2000	410,000
	Nelson, or Saskatchewan	Hudson Bay Territory	1400	—
	Churchill	"	900	—
	St. John	New Brunswick	400	22,000
	Connecticut	United States	400	11,000
	Hudson	"	325	14,000
	Delaware	"	300	12,000
	Susquehanna	"	450	28,500
	Potomac	"	400	15,000
	James	"	450	10,500
	Roanoke	"	350	18,000
	Pedee	"	350	14,000
	Santee	"	350	16,000
	Savannah	"	400	10,800
	Altahama	"	400	18,000
	Apalachicola	"	600	21,000
	Mobile	"	550	47,000
	Grande del Norte	United States & Mexico	1400	245,000
	San Juan	Central America	120	17,500
South American Section.	Amazon	Peru, Brazil	3900	2,500,000
	Orinoco	Venezuela	1200	400,000
	La Plata	Brazil	350	
	Parana	La Plata	2800	1,240,000
	Uruguay			
	Atrato	New Granada	300	11,000
	Magdalena	"	860	98,000
	Essequibo	Guiana	600	84,000
	Demerara	"	200	3,500
	Berbice	"	360	7,000
	Corentyn	"	470	20,000
	Surinam	"	350	12,000
	Maroni	"	400	18,000
	Maranhao	Brazil	360	—
	Paranhyba	"	750	—
	San Francisco	"	1500	254,000
	Grande do Belmonte	"	500	—
	Colorado	La Plata	600	—
	Negro	"	800	—

The Atlantic—its Currents.

178. "There is a river in the ocean. In the severest droughts it never fails, and in the mightiest floods it never overflows. Its banks and its bottoms are of cold water, while its current is of warm. The Gulf of Mexico is its fountain, and its mouth is in the Arctic Seas. There is in the world no other such majestic flow of waters. Its current is more rapid than the Mississippi or the Amazon, and its volume more than a thousand times greater. Its waters, as far out from the Gulf as the Carolina coasts, are of an indigo blue. They are so distinctly marked that their line of junction with the common sea-water may be traced by the eye. Often one half of the vessel may be perceived floating in Gulf-Stream water, while the other half is in the common water of the sea; so sharp is the line, and such the want of affinity between those waters, and such, too, the reluctance, so to speak, on the part of the Gulf Stream to mingle with the common water of the sea." Thus the eloquent author of the "Physical Geography of the Sea" describes the celebrated *Gulf Stream*, the most wonderful and important of all the great currents of the ocean.

179. The north-east and south-east trade-winds, blowing steadily towards the equator, impart to the surface waters over which they blow a tendency in the same direction. The south-west and north-west drifts thus produced meet in the tropics, and finally assume, and flow in, a westerly direction as the great *equatorial current* of the Atlantic. This immense current flows from the African coasts towards Brazil with a velocity of from 20 to 60 miles a day, and an average surface temperature of 75°, or about 5° lower than the water which it traverses. At first one hundred and sixty miles broad, it gradually widens to over four hundred miles as it approaches the South American coasts. Off Cape St. Roque it bifurcates; one branch, the *Guiana* current, reinforced by the waters of the Amazon and the Orinoco, flows with a velocity of 18

miles a day at the surface, but of only 9 miles at its bottom, at a depth of 50 fathoms.[1] Entering the Caribbean Sea through the numerous passages between the islands of the Lesser Antilles, the now much-warmer waters press through the Channel of Yucatan, and proceed to make the circuit of the Gulf of Mexico, where, under a tropical sun, they acquire a still higher temperature and velocity, and finally flow through the Straits of Florida as the *Gulf Stream*. In the Channel of Florida the Gulf-Stream is thirty-two miles wide, and moves at the rate of four or five miles an hour, and has a mean temperature of 81° F. Thence it proceeds towards Newfoundland in a direction almost parallel to the American coast, from which it is separated by a belt of cold water, the southerly prolongation of the Arctic current. The division between the two streams is so marked that a vessel may have her bows in warm, and her stern in cold, water. So abrupt is the change from a high to a low temperature, not only at the surface, but also to great depths, that off Massachusetts the line of separation, technically termed the "Cold Wall," is nearly perpendicular. There are also alternate streaks of warm and cold water in the stream itself, due most probably to the occasional "cropping up" of the cold under-water, and the "interlacing" at the surface of the cold water of the contiguous Arctic current with the warm water of the Gulf Stream. In its passage across the Atlantic, the latter gradually widens from 32 miles in the "Narrows," 150 miles off Charlestown, to 300 off Sandy Hook. In proportion to the increase in width it decreases in temperature and velocity. Starting with a velocity of from 70 to 120 miles a day, its speed is gradually abated, until south of the Grand Banks its waters are so diffused that its existence as a distinct current is entirely destroyed. The diffused but comparatively warm surface-water still preserves a perceptible easterly motion, and off the Azores merges partly into the sluggish north-easterly,

[1] Sir. G. Nares' Reports to the Admiralty on the *Challenger Expedition*.

and partly into the southerly, drifts. The former, generally regarded as the true "prolongation" of the Gulf Stream, extends to the British and Norwegian coasts, and is traceable even in Barents Sea and along the west coast of Greenland, thus forming counter-drifts to the East Greenland and Davis' Strait currents respectively. But though the Gulf Stream may aid this north-easterly set of the Atlantic towards the Arctic basins, by a constant supply of warm water from the Mexican Gulf, still the drift which bathes the coasts of Britain and Norway, and ameliorates their otherwise rigorous climate, is most probably a part of the natural overflow of the warm waters of the tropics towards the poles, and would exist were there no Gulf Stream.[1] The portion directed into the Bay of Biscay, along the northern coast of the Spanish peninsula, is deflected thence to the north-west as *Rennell's current.*

180. From the diffused warm-water area which marks the termination of the true Gulf Stream, there is also a southerly drift between the Azores and the coast of Spain. The *North African current* thus formed, being deflected by the north-western coast of Africa, sweeps to the south-west, and bifurcates off Cape Verd, the main portion curving towards, and finally joining, the North Equatorial current; the rest, bending round the African coast as the *Guinea current*, are also swept to the west with the South Equatorial current. Now, wherever a circular motion is given to any area of water, all the floating substances in that area will accumulate together near the centre, where the motion is less felt. In the North Atlantic, the inner portions of the Equatorial current, Gulf Stream, and African current form a continuous revolving current, enclosing an area of not less than 10,000 miles in circumference of comparatively still, and near the centre absolutely stagnant, water. The effect of the circular motion imparted by the great currents mentioned, is to "slough off" the drift-wood and sea-weed, and other floating *débris*, towards

[1] Lawson (*Physical Geography*).

the centre, and thus the vast area known as the Sargasso Sea has been formed. It is so thickly matted with weeds (chiefly *Fucus Natans*) that the speed of vessels passing through it is much retarded. But the Gulf Stream, and probably the other currents also, vary their position according to the season, the northern limit of the Gulf Stream being in winter about 40° to 41° N. lat., and in summer from 45° to 46°. Similarly, the limits of the Sargasso Sea vary according to the seasons, the storms, and the winds, but its *mean position* year after year is the same. Areas of comparatively still or stagnant water are also found in all the other great oceans—in fact, wherever there are return currents.

181. Whether the north-easterly drift between the Icelandic and Norwegian coasts be a direct prolongation of the Gulf Stream, or a natural flow of the warm tropical waters towards the pole, the climatical influence of the Gulf Stream is undoubtedly great. This vast current, the greatest and most important "river in the ocean," conveys into the temperate zone of the Atlantic an amount of heat equal to one-fourth the total amount received by the whole area of that ocean from the sun. Let the Gulf Stream be stopped, therefore, and the North Atlantic would be instantly deprived of at least one-fourth of its supply of heat, with what result to the now habitable and flourishing states of Western Europe may be imagined. The iceberg-laden Arctic currents would then pour their glacial waters far south into the Atlantic, and so chill the overlying air, that the westerly winds, instead of being, as at present, moist and warm, would be piercingly cold.

182. As regards the *course* of the Gulf Stream, it necessarily issues due north from the Straits of Florida; and were the earth stationary, and the ocean uninterrupted by land, it would preserve a due north course towards the Polar Sea. But its actual course is to the north-east. Looking at its general parallelism to the shores of the United States, a hasty

observer would most probably infer that they are the cause of the easterly deflection of the stream. Were it so, its warm waters would most certainly bathe the American coasts from Florida to Newfoundland. Is this the case? No. From Newfoundland to Cape Hatteras, if not beyond, there is a shore-belt of cold water from the north, the southerly prolongation of the Labrador current. The north-easterly course of the Gulf Stream is due to the modifying influence of the earth's diurnal rotation, owing to which all currents from these tropics to the poles have an easterly tendency; and, conversely, all currents *from* the poles towards the equator incline to the west.[1]

183. As regards the *cause* of the Gulf Stream, it is improbable that—although the joint effect of the north-east and south-east trades may be the *primum mobile* of a surface drift, as the Equatorial current virtually is—such a vast, constant deep-sea current as the Gulf Stream can be produced or impelled by the mere "piling up" of the water in the confined area of the Mexican Gulf. For it is evident that, were this the sole cause of the current, it would, as soon as it emerged from the Narrows and found sea-room, spread itself broadly out almost in the immediate neighbourhood, and most certainly would not hold on its way, furrowing the ocean for three thousand miles, a veritable "river in the ocean." Besides, if the trade winds be directly or indirectly the cause of the Gulf Stream, how is it that another current runs side by side with it along the American coast in an exactly opposite direction? Assuredly the winds that prove powerful enough to produce a constant current of such a magnitude and velocity as the Gulf Stream, would hold in check, if not altogether deflect, the comparatively sluggish flow from the north. If, therefore, the winds *alone* are the cause of all currents, it is most remarkable that there should be in the same

[1] The influence of the earth's rotation on the *course* of currents has been already discussed in Art. 134.

area two contiguous currents flowing in exactly opposite directions. The Gulf Stream, therefore, is not, and could not possibly be, produced by winds alone, even if much more stronger and continuous than the trades, but is simply the natural overflow of the heated waters of the tropics towards the poles, thus compensating the influx of polar waters towards the equator—a circulation due, as we have already remarked (Art. 129), to differences in specific gravity or density, arising from differences of temperature and salinity, and which would exist were there no aerial currents whatever.

184. The Gulf Stream, with its heated waters, contrasts strongly with the cold, iceberg-laden Arctic Current. Two well-defined currents set out from the north polar regions into the Atlantic. The *East Greenland current*, flowing in a southerly direction between Iceland and Greenland, unites off Cape Farewell with the *Davis Strait current*, coming from Baffin Bay. The united streams flow south as the *Labrador current*, and after sending a minor stream into the Gulf of St. Lawrence through the Strait of Belle-Isle, curve round Newfoundland, and off the Grand Banks meet with the warm current from the Mexican Gulf. Being heavier, one portion of the Arctic current sinks below the Gulf Stream, and enters the Caribbean Sea as an under-current. The other portion turns to the south-west, and proceeds towards Florida as the *United States counter-current*—thus flowing side by side with the Gulf Stream, but in an exactly opposite direction. "The Arctic current thus replaces the warm water sent through the Gulf Stream, and modifies the climate of Central America and the Gulf of Mexico,—which, but for this beautiful and benign system of aqueous circulation, would be one of the hottest and most pestilential in the world."

185. The southern portion of the great Equatorial current, deflected to the south-west off Cape St. Roque, becomes the *Brazil current* of the South Atlantic Ocean. Flowing at

a distance of about 250 miles from the coast,[1] its initial velocity of 25 miles a day is greatly reduced by the cross stream of the La Plata, and is finally arrested by the Cape Horn current. Before crossing the La Plata, however, the larger portion of this current seems to be deflected due east as the *Southern connecting current*, and either curves to the north past the Cape of Good Hope—thus uniting again with the South Equatorial current, as a part of the Gulf Stream does with the northern portion of the same current—or is continued into the Indian Ocean, thus forming part of an easterly drift extending from the La Plata to New Zealand. Such are the principal currents of the Atlantic Ocean, distinguished from those of the Indian and Pacific currents not only by a greater velocity, and a generally more marked character, but also by their importance in the navigation of the stormiest but most frequented of all the great oceans, and their influence in modifying the climates of countries bordering upon it. And when we reflect that these countries are mainly inhabited by the most civilized nations of the earth, the part played by this ocean in the promotion and diffusion of a higher civilization is surely worthy of careful consideration and earnest study.

[The following extract from the *New York Herald* entitled "The Cruise of a Bottle," will probably prove interesting and useful, as illustrating the drifts and currents of the Atlantic Ocean :—" The bottle picked up on South Beach, near Fort Morgan, at the entrance of Mobile Bay, tells an interesting story of the winds and waves. This waif was thrown off the ship *Hesperia*, bound to London from South Australia, as she was just south of the Azores (about 37° N. lat., and 28° W. long.), on May 12, 1878, and was reported from the Alabama coast on the 22nd October 1880. It must, therefore, have been drifting a little over two years, which it has consumed in making the circuit of the equatorial Atlantic and the Mexican Gulf. The course pursued by this little 'tally put upon the winds'

[1] The intermediate space is occupied by variable currents.—*Page.*

by Mr. Wragge, a scientific voyager in the *Hesperia*, can be pretty accurately determined. During the month of May 1878, when the bottle was committed to the sea, the barometric observations in the Atlantic demonstrate the prevalence of a large area of high pressure (30·20 inches) in the region south of the Azores, and around its northern side a strong band of westerly and north-westerly winds drawing in the anti-cyclonic direction. During the first twenty days of its voyage the bottle was under the pressure of these westerly and northerly winds, and the consequent ocean current which they induced, so that its inevitable course was toward the island of Madeira and the Canaries, and thence south-westwardly off the Cape Verd into the North Equatorial current. In 1843, Captain Beecher, of the Royal Navy, charted a number of probable tracks pursued by bottles thrown out to test the rate of the equatorial currents, and the mean rate at which they travelled in this marine area was 10·6 miles per day. He found also that bottles thrown off into the North Equatorial drift travelled much slower than those started from points nearer the Equator, and in the axis of the north-east trade-wind belt. Thus a bottle thrown over from the ship *Racehorse* in 12° 12′ N. lat., and 65° 50′ W. long., April 17, 1836, was picked up April 22 at Bonaire, having made 150 miles in five days. But a bottle thrown from the ship *Dunmore* in 1823, in 27° 4′ N. lat., and 28° W. long., on the north-eastern margin of the Sargasso Sea, reached Cuba, a distance of 3,200 miles, in 437 days, making on an average less than nine miles a day. The bottle from the *Hesperia*, just picked up on the Mexican Gulf coast, was approximately under the same wind and wave influences which bore the *Dunmore's* waif; and hence the former, traversing the Equatorial current and passing through the Caribbean Sea into the Gulf of Mexico, making a total circuit of 5,500 miles, travelled at about the same mean rate—eight miles a day. This bottle cruise, performed unnoticed amid the trackless wastes of the equatorial seas, though no living soul can tell its vicissitudes and variations from day to day, declares *the regularity of oceanic circulation*, and its history will be highly prized by navigators and geographers."]

THE ATLANTIC.—ITS DEPTH, AND CONFIGURATION OF ITS BED.

186. Previous to the recent scientific exploration of the Atlantic, depths of forty and even fifty thousand feet were occasionally reported, and its basin was regarded as a vast unbroken canal-like abyss, deepest along a middle line between the shores of the Old and the New Worlds, and gradually shoaling on either side. This idea, however, has been entirely dispelled by the researches of the *Challenger* and other scientific expeditions. Instead of a middle line of maximum depth, it is shown that a most remarkable ridge or submarine plateau extends from Cape Farewell on the north to Tristan d'Acunha on the south, generally following the outline of the coasts of the New and Old Worlds, thus repeating under water the S-shaped form of the shores of the Atlantic. The course of this great central ridge, which has an average elevation of 1,900 fathoms below the surface, may be roughly marked by a line drawn from Cape Farewell parallel to the coasts of Labrador and Newfoundland to the Azores; thence sweeping round to St. Paul's Rocks, and following the Equator as far as 12° W. long., where it turns suddenly south by Ascension to Tristan d'Acunha. The first portion of this central ridge is comparatively broad; south of the Azores it gets narrower, but widens out again south of Ascension, and between the Cape of Good Hope and the La Plata is nearly thirty degrees wide. Two lateral ridges are given off—one in lat. 10° N., connecting with the South American coast at Cape Orange; another, of less elevation, connects with the South African coast near Cape Voltas. Whether the main ridge is prolonged south of Tristan d'Acunha into the Antarctic plateau is as yet uncertain, but most probably it is separated from the South Polar elevations by an area of depression extending along the parallel of lat. 50° S. from the Falkland Islands to the meridian of the Cape.[1]

[1] J. J. Wild, *Thalassa* (Marcus Ward).

187. These submarine ridges divide the Atlantic into four more or less well-defined basins [1] :—(1) The *Eastern* basin, between the central ridge and the coasts of Europe and Africa, from Ireland to the Cape ; (2) the *North-Western* basin, between the central ridge and the American coasts, from the Grand Banks to Trinidad ; (3) the *South-Western* basin, between the South American coast and the central ridge ; (4) what may be called the *Southern* basin, south of lat. 50°, and merging indefinitely into the *Antarctic basin.* As regards *depth*, the three basins of the Atlantic proper—that is, north of the Cape and Falkland Islands—exceed 2,000 fathoms. The eastern and north-western basins have average depths of 2,500 and 3,000 fathoms respectively. The more considerable depressions are (*a*) a nearly circular depression between Cape Verd Islands and the central ridge in the eastern basin ; (*b*) an elongated depression, somewhat in the shape of a boot, between the Azores, Bermudas, and the West Indies ; (*c*) a nearly similar oblong trough in the south-western basin occurs between Ascension and Tristan d'Acunha on the east, and Fernando Noronha, Trinidad, and Martin Vaz, on the west. The *greatest depth* ascertained in the Atlantic, about 80 miles north of St. Thomas, was 3,875 fathoms, or about 4½ miles. About 150 miles north of this a sounding of 3,697 fathoms was obtained. Within the same basin the American ship "Gettysburg" obtained two soundings of 3,593 and 3,370 fathoms respectively. So that the deepest part of the Atlantic lies north of the Virgin Islands, along the meridian of 65° W. long.

188. Special names have been given to the most remarkable submarine elevations in the Atlantic; thus the broad ridge between Ireland and Newfoundland, along which the submarine telegraph lines are laid, is called the *Telegraphic Plateau*—while the northern and southern portions of the

[1] These basins are clearly shown in the "Contour Map of the Ocean," which forms the frontispiece of this work.

great central ridge are respectively distinguished as the *Dolphin Ridge* and *Challenger Ridge*. The lateral ridges are usually referred to under the general name of *connecting ridge*. Another peculiar elevation extends from Cape Rocca to Madeira, and includes the well known Josephine Banks. The belt of water along the Norwegian and British coasts is so shallow, that were the level to fall 100 fathoms, the British Islands would be connected by dry land with France, Belgium, Holland, and Denmark, and separated from the Scandinavian peninsula only by a narrow channel.

[As regards the *nature of the bottom* of the Atlantic, the belt to about 400 fathoms is generally covered with sand and débris, washed from the beach or brought down by rivers; from 400 to 2,000 fathoms by the white "globigerina ooze," consisting of the broken and decomposed shells of *foraminifera*. "Grey ooze" is found at depths of 2,000 to 2,300 fathoms; still deeper areas are mostly covered by a "red clay," a silicate of alumina and iron. The pieces of pumice and other volcanic products which are found scattered extensively over the bed of the Atlantic, may of course be due to submarine eruptions, but the most probable supposition is that they were ejected on land and carried down to the sea, and, becoming "water-logged," ultimately sank to the bottom.]

The Atlantic.—Navigation and Commerce.

189. The canal-like configuration of the Atlantic Ocean, extending from the Antarctic on the south to the Arctic on the north, and the influence of the four vast and widely different continental land-masses forming its eastern and western limits, are the causes of several conditions most unfavourable to its safe navigation. Frequently disturbed by violent storms, which produce broken and dangerous waves of great magnitude, its complicated tidal-waves, and to some extent its strongly-marked and rapid currents, are all elements of danger in the navigation of the Atlantic. A thorough knowledge of the course and velocity of its currents, and the direction and

force of the prevailing winds, forms indeed one of the most valuable "aids" to the mariner, and is doubly necessary in this, the stormiest of all the oceans. When we reflect that Great Britain alone has nearly 12,000 sailing and steam vessels engaged in the "home" trade, and nearly 8,000 in the foreign trade, and that the total tonnage of British and foreign vessels which entered the ports of the United Kingdom in one year[1] amounted to 51,595,079 tons, we may imagine the vast extent of the trade carried on by this country alone over the basin of the Atlantic. But besides Great Britain there are the great maritime and commercial countries of France, Holland and Belgium, Denmark and Scandinavia, Spain and Portugal, on the one side, and the Dominion of Canada, the United States, and West Indies on the other; and, south of the equator, the minor but still important trading stations of Western and Southern Africa, and the great ports of South America. Of course the commerce of the Atlantic is not limited to the interchange of the productions of its own shores. Vessels laden with the produce of the maritime states of the Pacific and Indian Oceans, and even the North and South Polar regions, cross and recross its waters. The principal and most important routes are those connecting Great Britain and North America, more especially those between Liverpool, Glasgow, Cork, and London, and Quebec, Montreal, New York, Philadelphia, and New Orleans. Communication with South Africa is regularly kept up by mail steamers sailing from London and Southampton, *via* Madeira and St. Helena, to Cape Town, and thence north-east to Natal, India, and China, or due east to Australia and New Zealand. Direct communication between the Atlantic and Indian Oceans is also possible by the Mediterranean, *Suez Canal*, Red Sea, and Arabian Sea. The route to South America from Western Europe passes by Madeira and Cape Verd Islands, to Pernambuco, Bahia, Rio Janeiro, Monte

[1] 1873.

Video and Buenos Ayres, the Falkland Islands, and round Cape Horn, or through Magellan Straits, into the Pacific. The *north-east passage*, from the Atlantic to the Pacific, round the northern shores of Asia and Behring's Strait, and the *north-west passage*, by Davis Strait, Baffin Bay, Barrow Strait, Melville Sound, and Arctic Ocean (the former may occasionally, but the latter can never, be used), have been already noticed. The vast extent of the Commerce centred in the basin of the Atlantic may perhaps be most clearly seen from a tabulated statement of the principal articles imported by, and exported from, the countries on its shores, together with their total value, according to the latest official returns. As an aid to estimate rightly the trade monopolized by Great Britain and Ireland, besides the value of the total imports and exports of each country, the value of the exports to, and imports from, the United Kingdom is also given. Great Britain is indeed the mart of all the productions of the world, and the centre of distribution to all other countries; the raw materials, which pour into it from almost every part of the globe, are re-exported after her manufacturing skill has increased their value a hundredfold;[1] her insular position off the western shores of Europe gives her the command of the Atlantic Ocean; all the more frequented water-ways of the world are controlled by her; in every ocean her fleets of trading and war vessels are found; with her vast colonies and possessions she forms an Empire upon which the sun never sets; and her advanced posts on the borders of every continent are always centres of enterprise for a trade that braves every peril, and knows no repose.[2]

---

[1] Th. Lavallée, *Military Geography* (Stanford).

[2] Ch. Dupin (*Force Commerciale de la Grande Bretagne*).

190. COMMERCE OF ATLANTIC MARITIME STATES.

*** *The numbers given in this list are taken from the latest official returns.*

1	2	3	4	5	6	7	8
Country.	Principal Imports.	Total Value.	Principal Exports.	Total Value.	Principal Ports.	Value of Imports from Gt. Britain & Ireland.	Value of Exports to Gt. Britain & Ireland.
		£		£		£	£
Norway	Manufactured goods, coal, wine, corn, colonial and foreign produce.	9,558,100	Timber, fish, ice, tar.	6,040,000	Christiania, Bergen, Drammen.	1,112,398	2,275,106
Sweden	Manufactured goods, coal, wine, salt, and colonial produce and machinery.	16,000,000	Timber, fish, iron, oats, ships.	12,500,000	Stockholm, Göteborg, Malmö, Norkœping.	1,686,305	6,852,291
Denmark	Cotton, linen, and woollen goods, colonial produce, salt, wine, coal, iron.	12,523,240	Agricultural produce, oilcake, corn, butter, bacon, fish, hides, tallow.	9,132,301	Copenhagen.	1,526,362	4,584,544
Holland	Manufactured goods, iron and machinery, colonial produce.	62,577,869	Butter, cheese, cattle and sheep, colonial produce.	45,115,589	Amsterdam, Rotterdam, Middleburg.	9,303,090	21,465,591
Belgium	Colonial produce, raw silk, cotton, and wool.	General. 94,263,792 Special. 56,047,712	Coal, hardware & machinery, flax, hemp, silk, woollen, linen, and cotton goods.	General. 80,166,992 Special. 42,972,588	Antwerp, Bruges, Ostend.	5,525,705	12,386,625

COMMERCE OF ATLANTIC MARITIME STATES.—*(Continued.)*

1	2	3	4	5	6	7	8
		£		£		£	£
England	Colonial produce, raw cotton, silk, wool, tallow, hides, wine, timber, tobacco.	368,770,742	Manufactured goods, hardware and machinery, cutlery, clothing, leather, coal, earthen and tin ware.	192,848,914	London, Liverpool, Bristol, Hull, Newcastle, Sunderland, Yarmouth, Southampton, Plymouth, Swansea, Cardiff, Whitehaven.	—	—
Scotland	Raw cotton, flax, hemp, wool, silk, timber, and colonial produce.		Manufactured goods, cattle, sheep, fish, coal, iron.		Glasgow, Leith, Dundee, Aberdeen, Montrose, Greenock.	—	—
Ireland	Colonial and foreign produce, coal, timber, wool, iron, hardware, salt.		Agricultural produce, linen, porter and spirits, copper ore.		Belfast, Dublin, Cork, Dundalk, Limerick, Wexford, Waterford, Galway, Londonderry.	—	—
France	Raw cotton and silk, wool, timber, metals, coal, colonial produce.	178,438,960	Silk, cotton, woollen, and linen goods, wine, brandy, jewellery, corn.	134,792,280	Marseilles, Bordeaux, Nantes, Rochelle, Havre, Boulogne, Calais.	14,824,885	41,378,896

COMMERCE OF ATLANTIC MARITIME STATES.—*(Continued.)*

1	2	3	4	5	6	7	8
		£		£		£	£
Spain	Colonial and foreign produce, manufactured goods, fish, coal, timber, iron, and machinery.	15,910,016	Wine, fruits, wool, minerals, silks.	17,253,066	Barcelona, Cadiz, Seville, Valencia, Malaga, Santander.	3,210,926	9,115,394
Portugal	Manufactured goods, colonial produce.	—	Wine, fruits, cattle, cork, salt.	—	Lisbon, Oporto, Setubal.	2,116,094	3,319,986
Morocco	Cotton and other manufactured goods.	—	Wool, maize, beans.	—	Tangier, Mogador.	191,292	391.369
Western Africa (Sierra Leone, Gambia, Gold Coast, Lagos, &c.)	Manufactured goods, hardware, provisions, tobacco, wine.	—	Palm oil, ivory, gum-copal, cocoa nuts, ginger.	—	Freetown, Bathurst, Lagos, Cape Coast Castle, Accra, Dixcove.	1,038,971	1,213,270
Cape Colony	Manufactured goods, coffee, sugar, rice.	5,158,348	Wool, diamonds, ostrich feathers, copper ore, wine, hides, skins, dried fruits, grain.	3,634,073	Cape Town, Port Nolloth (Port Elizabeth, East London, Mossel Bay).	3,821,279	3,699,012
Canada	Manufactured goods, hardware and machinery, colonial produce.	81,961,251	Agricultural produce, timber, grain, fish, oil, hides, pearl-ash, and bot-ash.	71,503,535	Quebec, Montreal, Halifax, St. John	5,926,908	8,874,257

COMMERCE OF ATLANTIC MARITIME STATES.—(*Continued*).

1	2	3	4	5	6	7	8
		£		£		£	£
United States	Manufactured goods, wine, and colonial produce.	89,158,408	Raw cotton, wheat flour, tobacco, timber, agricultural produce.	139,666,990	New York, Boston, Philadelphia, Baltimore, New Orleans (San Francisco).	14,552,076	89,146,170
Mexico	Cotton, woollen, and linen goods, machinery, fire-arms.	5,697,000	Silver, gold, copper, sugar, coffee, mahogany, hides, logwood & other dyes.	5,087,000	Vera Cruz, Tampico, Campeachy (Mazatlan, Acapulco).	773,331	507,082
Central America..	Manufactured goods, hardware.	1,897,822	Coffee, indigo, mahogany, hides, tobacco, cotton, cocoa, sugar.	3,374,560	Belize, Omoa, S. Juan de Nicaragua, Truxillo (Realejo).	732,018	968,438
British West Indies.....	Linen, cotton, and woollen goods, hardware, machinery.	5,739,010	Sugar, coffee, molasses, rum, cotton, cocoa, tobacco, mahogany, logwood, indigo.	5,961,871	Kingston, Nassau, St. John, Falmouth, Montego Bay, Bridgetown, Port Spain.	2,102,766	4,230,592
Haiti and San Domingo.....	Manufactured goods.	Haiti, 1,180,000 San Domingo, 350,126	Coffee, cotton, mahogany, &c.	Haiti, 1,300,000 San Domingo, 301,120	San Domingo, Porto Plato, Port-au-Prince, Cape Haitien.	333,507	187,367
Cuba and Porto Rico	Chiefly cotton goods.	—	Unrefined sugar, tobaccos, cigars, &c.	—	Havannah, Manzanillo, Aguadillo	1,889,960	1,804,872

COMMERCE OF ATLANTIC MARITIME STATES.—*(Continued).*

1	2	3	4	5	6	7	8
		£		£		£	£
Colombia	Manufactured goods, and hardware.	1,465,785	Peruvian bark, skins, furs, coffee.	2,895,579	Aspinwall, Porto Bello, Cartagena, (Panama, Buenaventura).	1,031,952	932,936
Venezuela	Cotton and linen, and other manufactured goods.	3,008,674	Coffee, copper ore, cocoa, tobacco, dyes, hides.	3,222,507	La Guayra, Maracaybo.	473,281	98,349
British Guiana ...	Manufactured goods.	2,150,714	Sugar, rum, timber, coffee, cotton, pepper.	2,507,571	Georgetown, New Amsterdam.	841,322	1,928,535
French and Dutch Guiana	Do.	—	Do.	—	Paramaribo, Cayenne.	—	—
Brazil	Cotton, linen, and woollen goods, wrought and unwrought iron.	8,947,960	Raw cotton, sugar, coffee, cocoa, hides, dyes, indiarubber, diamonds, gold.	9,233,600	Maranhao, Pernambuco, Bahia, Rio Janeiro, Para.	5,577,952	4,650,485
Uruguay	Cotton & woollen goods, hardware, timber, and agricultural implements.	2,840,000	Cattle, hides, tallow.	2,924,931	Monte Video.	977,866	644,066
Argentine Confederation	Iron (wrought and unwrought), cutlery, hardware, leather goods, cotton, woollen, and linen goods,	—	Wool, tallow, hides, skins, horns, furs, bullion.	—	Buenos Ayres.	2,317,638	1,099,938

191. The principal articles of *import* into the United Kingdom are—corn and flour, raw cotton, wool, sugar, timber, tea; and of *export*—cotton, woollen and linen goods, iron, steel, coal, and machinery. Their value in 1878, and whence imported and exported, are shown in the following table:—

PRINCIPAL IMPORTS.

Articles.	Value.	Imported chiefly from
	£	
Corn and flour ..	59,064,875	United States, France, Germany, Russia.
Raw cotton	33,519,549	United States, East Indies, Egypt, Brazil.
Wool	23,128,234	Australia, Cape Colony, Russia, Germany.
Timber	13,974,424	Canada, Norway and Sweden, Germany, Russia.
Tea.....	13,048,787	China.

PRINCIPAL EXPORTS.

Articles.	Value.	Exported chiefly to
	£	
Cotton goods.....	65,935,555	Almost everywhere.
Woollen goods ...	20,635,587	France, Germany, Holland, Australia, United States.
Iron and steel ...	19,393,240	France, Holland, United States, Canada, India, Australia.
Machinery	7,497,950	India, British Colonies generally, France, Spain, Russia.
Coal	7,330,474	Chiefly to the maritime countries of Western Europe.
Linen goods	6,928,877	France, Germany, United States, Brazil.

The Atlantic.—Historical Notes.

192. In the present day the more civilized nations inhabit the shores of the North Atlantic Ocean, but formerly civilization was most largely diffused along the shores of the Mediterranean. It was in that great inland sea, in itself almost an ocean, that navigation made its earliest efforts, and the comparative shortness of the distances between port and port rendered the transit easy, even to imperfect vessels. [1] From their ancient seaports of *Tyre* and *Sidon* the adventurous Phœnician sailors—after thoroughly exploring the Mediterranean, and establishing many flourishing colonies, of which *Carthage* soon became pre-eminent—pushed boldly through the Straits of Gibraltar, and founded *Gades* (now Cadiz), on the Atlantic coast of the Iberian peninsula. Further explorations resulted in the discovery of the *Canary Islands* to the south, and the *British Isles* to the north. The Greeks next swept the Mediterranean, and from the Greek colony of *Massila* (Marseilles) an intrepid Grecian sailor followed the coasts of Spain and Gaul, and actually coasted the eastern coast of Britain as far as the *Orcades* (Orkneys), and thence sailed north to *Thule*, the precise locality of which is uncertain.

193. The Punic Wars resulted in the destruction of Carthage, and in the ascendancy of the Roman power. The invasions of Britain by Julius Cæsar and other Roman generals led to the frequent navigation of the English Channel and adjacent seas; and the rude barks of the Jutes, Saxons, and Angles, soon after began to cross the North Sea. Then followed the Danes and Scandinavian Vi-kings, whose savage descents on the more fruitful southern coasts spread terror and dismay for centuries. The reign of Alfred witnessed a victory gained by the *first English fleet*. About this time, too, the Baltic was navigated, and the North Cape passed; and in 861 the

[1] See Admiral Smyth's instructive memoir on "*The Mediterranean.*"

Faroe Islands were discovered by a Scandinavian vessel. Thence some Norwegian chiefs were driven westwards, during a storm, to *Iceland*, which was speedily occupied and colonized. In 950 the Icelander Gunbiörn discovered *Greenland*, first colonized in 985. The glory of the first discovery of the continent of *America* is undoubtedly due to adventurers from Greenland, who, in 1001, came upon regions which they named Winenland, or Vine-land—probably so called from the abundance of a species of vine found there.

194. Spain and Portugal now took the lead in fostering a spirit of adventure and discovery, and *Madeira* was visited in 1419 by the Portuguese, Juan Gonsalez and Tristan Vaz.[1] In 1345 the Canary Isles were rediscovered; and about 1364 it is said that some sailors from Dieppe coasted the Gulf of Guinea. It is certain, however, that the Portuguese reached the mouth of the *Senegal* in 1440; and, six years later, European vessels anchored off the *Cape Verd Islands*. Two years after, Cabral discovered the *Azores*. The mouth of the *Congo* was reached by the Portuguese, Diego Cam, in 1484; and, two years later, Bartholomew Diaz sighted the *Cape of Good Hope*.[2]

195. The most important exploit of this period, and the prelude to the discovery of two vast continents, was the voyage of Columbus from Spain to the Canaries, and thence west across the Atlantic. On the 12th of October, 1492, Guanahani, or *San Salvador*, one of the Bahama Islands, was sighted by the great navigator, who, after visiting *Cuba*, and *Hispaniola* or *Haiti*, returned to Europe. Next year he sailed from Cadiz, and *Jamaica*, *St. Christopher*, *Dominica*, and other islands bordering on the Caribbean Sea, were discovered. On the north, *Newfoundland* had been discovered

---

[1] It is also asserted that this island had been discovered by Robert Macham, an Englishman, in 1344. Keith Johnston gives 1498 as the date of its discovery. See his admirable *Geography—Physical, Historical, and Descriptive.* (Stanford.)

[2] Originally called Cabo Tormentoso, the "Cape of Tempests."

by Cabot in 1457; and exactly forty years after, Vasco de Gama doubled the Cape of Good Hope, and opened the passage by sea to India.

196. Columbus had set out in 1492 with the idea that any lands he might discover to the west would be the opposite shores of the Indies, and thus originated the name *West Indies*. In 1498 the continent of America was first sighted west of the island of *Trinidad*. Amerigo Vespucci and Admiral Ojede, sailing from Cadiz in the year following, coasted the district now called *Venezuela*; the whole continent receiving its name "America" after Vespucci. On the 24th of April, 1500, De Cabral was driven on the coast of *Brazil*,[1] which Vespucci carefully explored from 1500 to 1504. In 1501, Corteral sailed from Lisbon to Newfoundland, and, following the coast west and north, discovered the river *St. Lawrence*, and the bleak and barren coasts of *Labrador*. The following year Columbus explored the shores of the *Mexican Gulf*.

197. In the previous year (1501) Tristan d'Acunha had been sighted by a Portuguese navigator of the same name, and on Ascension Day, Juan de Nova discovered the rocky islet of *Ascension*, and in the year following, *St. Helena*. Thomas Aubert visited Canada in 1508, and in 1512 Ponce de Leon, a Spanish navigator, coasted the peninsula of *Florida*. Balbao from the heights of Panama first saw the open expanse of the Pacific in 1513. An expedition was immediately fitted out to explore the newly-found ocean, and in 1516 Diaz de Solis traced the coasts of Brazil south, passed the bay of Rio Janeiro, and discovered the estuary of the *La Plata*. In the North Atlantic Bermudez made known the group called after him, the *Bermudas*. In September, 1519, Magellan sailed from San Lucar in command of a fleet of discovery, fitted out by Charles V. of Spain. Steering south past the La Plata, Magellan passed into the Pacific

[1] Cabral named it *Terra de Santa Cruz*—the land of the Holy Cross.

through the strait which still bears his name. Naming the adjoining land *Tierra del Fuego*, this intrepid navigator crossed the "Oceano Pacifico" to the Philippines, where he was murdered. One of his vessels, however, held on its way, and ultimately reached Spain—this vessel, the "*Vittoria*," being thus the first to circumnavigate the globe.

198. The North American coast, from Florida to Newfoundland, was becoming gradually better known, and in 1534 *Canada* was explored by Cortier, and taken possession of by France. The attempts made to discover a North-east Passage round Norway and Northern Asia, or a North-west Passage through the North American Archipelago from the Atlantic to the Pacific, will be more particularly noticed in the historical notes on the Arctic Ocean; suffice it to remark here that in 1576 Martin Frobisher discovered the strait leading into Hudson Bay, and eleven years later John Davis sailed through *Davis' Straits*. *Hudson Bay* itself was explored by the English navigator Hudson, who perished there in 1610. Three years before, John Smith had sailed up *Chesapeake Bay*, and the *Straits of Le Maire* and *Staten Island* was discovered by Le Maire and Schouten, who then doubled the southern extremity of South America, naming it *Cape Horn*, in honour of Hoorn, the native town of Schouten. Along the American and African shores of the Atlantic, discovery was soon followed by settlement, and thus the French occupied Canada and Louisiana—the intervening territory being settled by the English and the Dutch, with the exception of Florida, held by the Spaniards, who also conquered Mexico and the Western States of South America. Brazil was retained by the Portuguese, who also possessed themselves of the greater part of the western shores of Africa, and founded settlements at Senegambia, Guinea, and Angola. In 1652 the Dutch founded the Cape Colony; and the establishment of the Hudson Bay Company in 1670 led to more minute exploration of the northern coasts of North America. In fact,

by the year 1700 the coasts of the Atlantic were pretty accurately known, and much frequented. Since then the exploration of the other great oceans has been accomplished in such a manner, that the configuration, not only of the great continental land masses, but also of the smaller islands, and even reefs, banks, and shoals, has been accurately mapped out for the guidance of navigators.

199. What may be called the scientific exploration of the bed of the Atlantic dates from the year 1849, when the American Senate passed an Act authorising the employment of three vessels to assist Lieut. Maury in his researches. The officers of the United States Coast Survey devoted special attention to the "Gulf Stream." In 1871 the U.S.S. *Mercury* ran a line of soundings between Barbadoes and Sierra Leone. From 1868 to 1870, two of H.M.S., the *Lightning* and the *Porcupine*—explored the basin of the Atlantic from the Faroe Islands to the Straits of Gibraltar. The celebrated *Challenger* expedition, specially equipped for the scientific exploration of the deep sea, left England in December 1872, and proceeded south to Lisbon, Gibraltar, Madeira, and the Canaries, whence it crossed the Atlantic to the West Indies. Thence it went north to Halifax and Newfoundland, and returned to Bermuda. Then it crossed the Atlantic, by the Azores, to Cape Verd Islands, and recrossed it again to Bahia, whence it proceeded, by Tristan d'Acunha, to Cape Town, arriving there at the close of 1873. The vessel then skirted the Indian and Antarctic Oceans, and explored the Pacific more fully, arriving at Valparaiso in 1875. Sailing thence through Magellan's Straits, and touching at the Falkland Islands, the expedition returned to England on the 24th of May, 1876.

200. From 1874 to 1876, other vessels were employed in exploring the basin of the Atlantic—such as the German frigate *Gazelle*, H.M.S. *Valorous*, the Norwegian vessel *Voringen*, and the U.S.S. *Gettysburg*. The data thus supplied have enabled us to map out with considerable accuracy

the conformation of the bed of the ocean, and more especially that of the Atlantic. The main results of the more recent investigations are embodied in the little chart which forms the frontispiece of this work, and which the student would do well to examine very carefully.

[A full account of *Porcupine* and *Lightning* expeditions will be found in Sir C. Wyville Thomson's "Depths of the Sea," and of the *Challenger* expedition in "The Atlantic," by the same author, and in Sir George Nares' "Report to the Admiralty"; but the main results of recent observations are perhaps more clearly presented in Mr. J. J. Wild's admirable essay "Thalassa," a work which will probably prove more useful to the general student than the larger and more technical publications.]

NOTES ON THE PRINCIPAL SEAS BELONGING TO THE ATLANTIC.

201. The Atlantic Ocean is distinguished from all the other great divisions of the ocean by the number and magnitude of the "seas" belonging to it, of which the principal strictly inland seas are—the *Baltic*, the *Mediterranean*, the *Sea of Marmora*, *Black Sea*, and the *Sea of Azov*—all on its eastern side. It will be advisable, also, to give a few particulars relative to the *Caspian Sea*, although it does not belong to the Atlantic, but is in reality a vast salt-water lake.

The Baltic Sea.

202. The Baltic Sea lies in the north-west of Europe, and is bounded by Russia on the east, Prussia on the south, and Sweden

---

1. All the seas mentioned lie to the north of the equator, and hence belong to the *North* Atlantic. South of the equator there is no inland sea opening into this ocean, nor indeed any considerable indentations, if we except the Gulf of Guinea on the east, and the estuaries of the Amazon and the La Plata on the west.

2. Lat., *balteus*, a belt, *i.e.*, the "sea of belts"; Cf., Great Belt, Little Belt. Called by the Danes and Scandinavians the *Ost See*, *i.e.*, the "East Sea."

and Denmark on the west. It has an area of about 160,000 square miles, and an extreme length and breadth of 900 and 200 miles respectively. On the south it extends in an easterly direction for 300 miles, and then turns almost due north. It communicates with the North Sea by three narrow channels—the *Sound* (2 miles wide), between Sweden and Zealand; the *Great Belt* (8 miles), between Zealand and Funen; and the *Little Belt* ($\frac{3}{4}$ mile), between Funen and Jutland. The most frequented of these passages is the Sound; but all three open into the southern end of the winding and deep channel which separates Jutland from Sweden and Norway, of which the southern part, between Sweden and Jutland, is known as the *Kattegat*, and the northern part, between Jutland and Norway, as the *Skager-rack*.

203. The Baltic terminates to the north in the *Gulf of Bothnia*, an arm nearly 400 miles long, and from 40 to 120 miles broad; to the east in the *Gulf of Finland*, which runs nearly due east for 280 miles, with an average breadth of 60 miles. Further south is the *Gulf of Riga*, and a bend in the southern shore forms the *Gulf of Danzig*. The principal islands are—the *Aland Islands*, at the entrance to the Gulf of Bothnia; *Dago* and *Oesel*, at the mouth of the Gulf of Riga; *Gothland*, *Œland*, and *Bornholm*, off the coast of Sweden; *Rugen*, off the Prussian coast; *Zealand*, *Funen*, *Laaland*, and other islands of the Danish Archipelago. Of the numerous rivers entering it, the principal are—the Tornea, Pitea, Dal, &c., on the west; the Neva, Dwina, and Niemen, on the east; and the Vistula and Oder, on the south. The drainage area of the Baltic is estimated at 717,000 square miles—*i.e.* about one-fifth of the entire area of Europe, or nearly two and a-half times the area drained into the vastly greater Mediterranean Sea. The immense amount of fresh water discharged into the Baltic renders its waters comparatively fresh, the average proportion of saline ingredients being scarcely one-third that of oceanic water. The degree of salinity is least when the supply of river-water is greatest, the specific gravity of water in the Gulf of Bothnia being then only 1·004. The comparatively slight loss by evaporation being more than balanced by the supply of fresh river-water, there is consequently an *outflow* of the surface-water through the Baltic Straits

into the North Sea, but compensated to some extent by an *inflow* from the latter as an under-current.

204. As regards depth, the Baltic is throughout shallow in comparison with the open ocean, the deepest part being only 690 feet. The average depth is only 10 fathoms in the north, and 50 in the south. The débris discharged by numerous rivers entering it has so accumulated, that many river-mouths and harbours, formerly accessible, cannot now be approached by any but the smallest vessels. The Gulfs of Finland and Bothnia are also shallow, and obstructed by numerous islands and sandbanks. The navigation of the Baltic is, at the best, difficult and dangerous, and is entirely stopped during the winter, when the greater part of it is frozen over. The Baltic Straits are generally closed from December to April; and even the port of Christiania, in Norway, is occasionally ice-bound for four months. It is only in very severe winters that the southern parts of the Baltic proper are continuously frozen over. The shores of the Baltic are generally low—sandy in the south, and rocky round the Gulfs of Finland and Riga. On the south are several fresh water lagoons, or *haffs*, separated from the sea by narrow tongues of land called *nehrungs*.

205. Two remarkable physical phenomena in connection with the Baltic deserve notice—viz., the *formation of bottom ice*, and the *upheaval* of its northern, and *subsidence* of its southern, shores. Thin cakes of ice form on the bottom, and rise edgeways to the surface, sometimes in such numbers that the whole surface is rapidly covered with continuous sheets of ice. The *raised beaches* of Norway, and the occurrence of deposits of shells at elevations of 200 feet and upwards, both on the Swedish and Finnish shores of the Gulf of Bothnia, prove that the whole country to the north of the Baltic has been upheaved within a comparatively recent period. In the south, on the contrary, no raised beaches or elevated shell-deposits are met with; on the contrary, there seems to be undoubted proof of a general *subsidence* of South Sweden. Linnæus, in 1749, measured the exact distance of a certain stone from the sea. In 1836, the same stone was found to be 100 feet nearer the water than in 1749. The periodical rise and fall of the water known as the tides is inappreciable in this sea, if not altogether absent.

The Mediterranean Sea.

206. The Mediterranean,[1] by far the largest and most important inland sea in the world, lies between Europe on the north, Africa on the south, and Asia on the east. Its length, from the Straits of Gibraltar to the coast of Syria, is 2,300 miles, and its breadth varies exceedingly—from 1,000 miles between the Gulfs of Taranto and Sidra to 80 miles between Sicily and Tunis. Its broken and irregular northern shores contrast strongly with the bold and regular outline of the North African coast. The coasts of Spain and France are low, except at and near Cape Creux, where the Pyrenees terminate. The Italian coast from Tuscany to Naples is swampy, and borders on the Pontine Marshes. The western and eastern shores of the Adriatic contrast strongly—the former being low, while the latter is moderately high and rocky. The coasts of Greece, Turkey, and Asia Minor are on the whole bold, and the first, especially, being very irregular. That of Egypt is low and sandy. Westwards, the coasts of the Barbary States are generally regular, but containing several bays and harbours. Various parts of the Mediterranean are distinguished by special names—such as the *Gulfs of Lions*[2] and *Genoa*, the *Adriatic Sea*, the *Archipelago* or *Ægean Sea* on the north, the *Levant* on the east, and the *Gulfs of Sidra* and *Cabes* on the south. Of the islands, the more important are—the Balearic Isles, Sardinia, Corsica, Sicily, Malta, the Ionian Islands, Candia, Cyprus and Negropont, and other islands of the Archipelago. The area drained directly into the Mediterranean is only 300,000 square miles, scarcely one-third that drained into the smaller Black Sea. The principal rivers are—the Xucar (250 m.), Ebro (420 m.), Rhone (490 m.), Arno (150 m.), Tiber (210 m.), Po (460 m.), Adige (250 m.), Vardar, Struma, and the Maritza (320 m.), the Nile (3,000 m.), and the Mejerdah, Roumel, Shéliff, and Mulwia, from the Atlas Mountains.

[1] Lat., *medius*, middle; *terra*, land. Called by the Romans *Mare Internum*, and also *Mare Nostrum*, *i.e.*, "Our Sea." Known to the Arabs as the *Bahr-Rum*, the "Roman Sea." The modern Greeks call it the *White Sea*, in contradistinction to the "Black Sea."

[2] So called from the boisterousness of the sea at this part, and not from the city of Lyons.

207. Notwithstanding the immense amount of fresh water discharged into this sea, its waters are salter than those of the Atlantic —the proportion of saline ingredients being ·029 per cent., as against ·027 per cent. in the latter. Evaporation must therefore be extremely active; and it is indeed computed that three times as much water is evaporated as is supplied by all the rivers entering it. Were the Strait of Gibraltar closed, the level of the Mediterranean would be reduced until the amount of evaporation exactly balanced the supply of river-water. As it is, a strong *surface-current* flows from the Atlantic through the Straits of Gibraltar; the excess in level which would thus be produced, were there no compensating *outflow*, is counteracted by a smaller *under-current* flowing *into* the Atlantic. As the Mediterranean communicates with the ocean by a channel—the Straits of Gibraltar—lying parallel to the course of the tidal-wave, the tides are slight, the rise scarcely anywhere exceeding a few inches. As a commercial highway the Mediterranean is most important, lying as it does between the three great continents of the Old World. Its importance in this respect has recently been greatly increased by the construction of the *Suez Canal*, so that there is now a continuous waterway between the Atlantic and the Indian Oceans. A large proportion of the commercial, and all the mail and passenger traffic between England and India, now passes through the Canal, the route being about 5,000 miles shorter than that round the Cape of Good Hope.

208. The *Straits of Gibraltar*—bounded on the west by Cape Trafalgar and Cape Spartel, and on the east by Europa Point and Cape Ceuta—connect the Mediterranean with the Atlantic; the *Dardanelles* with the Sea of Marmora (170 miles long and 48 miles broad); the communication with the Black Sea being completed by the Channel of Constantinople, or Bosphorus. As regards depth, the Mediterranean is on the whole deep, and is divided into two unequal basins by a chain of shoals known as the Skerki, which extend from Sicily to Cape Bon in Africa. This remarkable submarine ridge rises in some places to within a few fathoms of the surface, and in the deepest parts sinks to 140 or 200 fathoms. The Mediterranean has an average depth of 1,200 fathoms in the western, and about 2,000 fathoms in the eastern,

basin. The maximum depth in the Strait of Gibraltar is about 500 fathoms. We cannot close this brief sketch of the Mediterranean better than in the words of Admiral Smyth, who, in his valuable survey, remarks that "the political and social events which have occurred on the shores of this remarkable part of the ocean are closely connected with the history of almost every country in the world; but, independently of its classical and historical associations, the Mediterranean still confers invaluable advantages upon the numerous occupiers of its coasts, and through them on the interior of the surrounding continents. It is, moreover, the great bond of intercourse between the nations of Europe, Asia, and Africa, although it appears as if destined to keep them asunder. Beautifully diversified with islands, and bounded by almost every variety of soil, its products are proportionately various; and from its communication with the Atlantic, it facilitates commerce with every part of the world."

209. Commercially, the Mediterranean is one of the most important water-ways in the world. The following table shows the total value of the imports and exports of the countries bordering on the Mediterranean in the year 1878 :—

Countries.	Total Value.		Value of Imports from Great Britain.	Value of Exports to Great Britain.
	Imports.	Exports.		
	£	£	£	£
Spain	15,910,016	17,253,066	3,210,926	9,115,394
France	178,438,960	134,792,280	14,824,885	41,378,896
Italy	42,832,104	41,631,577	5,363,838	3,252,459
Austria-Hungary	57,954,782	69,830,251	763,034	1,665,857
Turkey	18,500,000	10,000,000	7,748,007	4,779,103
Greece	4,500,000	3,000,000	982,037	1,763,064
Egypt	4,845,000	8,099,000	2,194,030	6,145,421
Tunis	1,100,000	1,300,000	45,995	345,214
Algeria	8,112,132	6,880,251	168,971	357,352
Morocco	1,082,662	1,214,882	191,292	391,369

The Black Sea.

210. The Black Sea[1] lies between European Turkey on the west, South Russia on the north, and Caucasia on the east. It is oval-shaped, and, including the Sea of Azov, has an area of 180,000 square miles. It is connected with the Mediterranean by the *Channel of Constantinople*, or Bosphorus,[2] the Sea of Marmora, and the *Dardanelles*. The Bosphorus is about 20 miles long, and in narrowest part scarcely half a mile wide, but deep throughout, and navigable for the largest vessels. Though much smaller than the Mediterranean, the Black Sea receives the drainage of an area three times as large—roughly estimated at 900,000 square miles, or nearly a fourth of the entire area of Europe. The principal rivers entering it are—from Europe, the Danube (1,630 miles), Dniester (700 miles), Dnieper (1,200 miles), and the Don (1,100 miles), which falls into the Sea of Azov; from Asia, the Rion, Joruk-su, Kizil-Irmak, and the Sakaria. The supply of fresh water exceeds that evaporated, hence the waters of the Black Sea are fresher than those of the Mediterranean; and hence, also, the strong outflow into the Mediterranean through the Bosphorus and the Dardanelles. The Sea of Azov is always, and the northern parts of the Black Sea sometimes, frozen over in winter. The latter is deep, and uninterrupted by islands or rocks; but its navigation is rendered dangerous by frequent sudden storms and heavy fogs.

The Caspian Sea.

211. Although the Caspian Sea is in reality a vast salt-water lake, and does not belong to the Atlantic like the previous seas, still a few particulars respecting it may be of use to the student. This sea lies on the south-eastern borders of Europe, having Caucasia on its western, and Persia on its southern, shores. It is the largest strictly-inland expanse of water in the world, being 640 miles long, from 100 to 200 miles broad, and covering an area variously estimated at from 130,000 to 180,000 square miles. It was called

[1] First called by the Greeks *Axenos*, "inhospitable"; afterwards changed into *Euxinos*, "hospitable." Called "Black Sea" by the Turks, on account of its dense fogs and storms.

[2] Greek, *Bous-póros*, "Ox-ford."

a "sea" by the ancients, who erroneously supposed that it communicated with the Northern Ocean; but although it is certain that no such connection has existed within historic times, it is evident that this isolated expanse is simply "a survival of that great central sea which at no remote geological period covered a large part of Northern Asia—the gradual upheaval of land having separated it from the Black Sea, Sea of Aral, and the Arctic Ocean." [1] The Caspian is also remarkable from the fact that its surface is below the general level of the waters of the globe.[2] The principal rivers flowing into the Caspian are—the *Volga* (2,200 miles), the longest of all European rivers, the *Ural* (1,150 miles), *Terek* (300 miles), *Kour* (550 miles), and the *Atrek*. The supply of river and rain water seems to be exactly equal to the amount evaporated, for were it greater or less, a corresponding alteration of level would be the result. When first cut off from communication with the ocean, the level of the Caspian was doubtless the same as that of the ocean; but once entirely enclosed, evaporation and supply being unequal—the former predominating—the level was gradually reduced, until it reached a point at which the waste and supply exactly counterbalanced each other; and so long as the present conditions exist unaltered, the present level will continue unchanged. The Caspian "has no tides; its waters are slightly salt [3]; it is shallow, stormy, of difficult navigation; and has but few indifferent ports."

---

[1] *Physiography and Physical Geography* (Blackwood).

[2] Ascertained to be 83 feet below the level of the Black Sea.

[3] Salinity about one-fourth that of the ocean.

George Philip & Son London &

II.

THE PACIFIC OCEAN.

The Pacific—its Boundaries and Extent.

212. The Pacific Ocean[1] is by far the largest expanse of water on the globe, being nearly double the size of the Atlantic, and having an area variously estimated at from fifty to one hundred millions of square miles. It extends from Behring's Strait on the *north* to the Antarctic Circle on the *south;* and is bounded on the *east* by the continent of America, and on the *west* by Asia and Australia. Unlike the Atlantic, its meridional extension is inferior to its equatorial dimensions, the distance in a direct line from Behring's Strait to the Antarctic Circle being a little over 9,000 miles, while along the equator the Peruvian coast on the east is fully 12,000 miles from the nearest islet of the Malay Archipelago on the west. Like the Atlantic, it opens out broadly into the southern sea, but instead of two comparatively wide channels as Davis Strait and the channel between Greenland and Norway, the only connection with the Arctic Ocean is by the narrow passage, scarcely fifty miles in width, of Behring's Strait. South of Cape Horn and Tasmania, the exact boundaries of the

[1] Formerly referred to in England as "The South Sea;" called by the Germans and French "The Great Ocean."

Pacific are, of course, purely imaginary, the limit on the east being along the meridian from Cape Horn to the Antarctic Circle; that on the west being an imaginary line running meridionally from South-west Cape, in Tasmania, to the Antarctic Circle. The *greatest width* of both the Atlantic and Pacific Oceans is under the direct line of the equator; but while that of the former is only 4,200 miles, that of the latter is upwards of 12,000 miles. Its *area*, as we have said, is variously estimated by different geographers. Dr. Keith Johnston estimates it at 67,810,000 square miles, or nearly twice the total water area of the globe, or about one-fourth of the entire surface of the globe. Corresponding to the Atlantic in meridional extension, the configuration or shape of the two great oceans is widely different. The long, contracted, canal-like basin of the Atlantic contrasts strongly with the immense oval-like expanse of the Pacific. The gradual and close approximation of the Asiatic and American continents north of the equator is imperfectly reproduced in the general south-easterly trend of the Malay Archipelago, Australia and New Zealand, and the southerly extension of the S. American coasts. The Pacific is thus nearly land-locked on the north, while on the south its waters merge indefinitely into the Antarctic Ocean, from Balleny Islands on the west to South Shetland on the east. If we consider the distribution of land and water as shown in the continental and oceanic hemispheres, it will be apparent that both the Pacific and Atlantic Oceans are but northerly extensions of the immense circum-terrestrial Southern Ocean—the Atlantic forming an elongated gulf, and the Pacific a vast bay, between the Old and New Worlds.

213. As a glance at the accompanying map will show, the general direction of the Pacific coasts are as follow:—(1) north-west from Behring's Strait to Anam; thence north-east along the East Indian Archipelago, East Australia curving south. (2) From Behring's Strait the American

coasts trend in a south-easterly direction as far as Panama; thence, bending round to Arica, they skirt the Andes, almost due south along the 71st meridian. The following table exhibits the countries on opposite sides of the Pacific :—

214. THE PACIFIC OCEAN.

Western Shores.			Eastern Shores.	
Asia.	Siberia	opposite to	Alaska.	North America.
	Kamtchatka...	"	British Columbia.	
	Japan (Corea, Manchooria)	"	United States.	
	China.....	"	Mexico.	
	Siam	"	Central America.	
	Anam, (Philippines).....			
Oceania.	Borneo	"	New Granada.	South America.
	Celebes		Ecuador.	
	New Guinea...		N. Peru.	
			S. Peru.	
	Australia	"	Bolivia.	
	New Zealand..		Chili.	
			N. Patagonia.	
			S. Patagonia.	

The Pacific—its Islands.

215. One of the most distinctive features of the Pacific Ocean is the vast number of islands and island-groups, some of which are volcanic, but by far the greater number are of coral formation. Most of the islands of volcanic origin are skirted, or entirely encircled, by coral reefs. The whole of the islands of the Pacific west of Australia are frequently called *Polynesia.*

216. In the North Pacific, the larger islands lie close to the eastern shores of Asia, and extend in an almost unbroken line from the peninsula of Kamtchatka to the Malay Archipelago—the largest island-group in the world. To the south

of the Sea of Okhotsk we have the large island of *Saghalien*, and the chain of the *Kurile Islands*, continued southwards in the larger *Japan Islands* of Jesso, Niphon, Sikokf, and Kiusiu. The *Loo Choo Islands* and *Formosa* extend the line nearly to the *Philippines* (Luzon, Mindanao, Palawan, &c.), and thence to the *Malay Archipelago*—of which the *Ladrones*, *Caroline*, *Pelew*, and *Sulu Islands*, *Gilolo Isle*, and the northern portions of Borneo and Celebes, are included in the North Pacific. The eastern basin of the North Pacific is greatly inferior to the western in the number and size of its islands. The principal are—*St. Lawrence* and *Gore Islands*, in Behring's Sea, which is bounded on the south by the chain of the *Aleutian Islands*. With the exception of *Kodiak Island*, off Alaska, and *Prince of Wales*, *Queen Charlotte*, and *Vancouver Islands*, off British Columbia, there are only a few small islets along the coasts of the United States, Mexico, and Central America. In the open ocean we have the volcanic group of the *Sandwich Islands*, and, further west, the small islets of *Marshall* and *Gilbert*.

217. In the South Pacific occur by far the larger number of groups of islets of coral formation, and larger islands of volcanic origin. Of the Malay Archipelago, the principal islands on the Pacific side are—*Borneo*, *Celebes*, *Moluccas*, Papua or *New Guinea*, *New Britain*, and *New Ireland*. Off the southeastern promontory of New Guinea we have the *Louisiade Archipelago;* but along the eastern coast of Australia, from Cape York to Cape Howe, there is an entire absence of any large islands, with the single exception of *Great Sandy Island*. Inside the Great Barrier Reef, however, there are a number of smaller islets. To the south of Australia we have *Flinder's Island* and *Tasmania*, and, further east, the two large islands (North and South) of *New Zealand*. North and east of New Zealand the islands are remarkably grouped together in a latitudinal belt, between the parallels of 5° and 25° S. lat. The principal groups from west to east are—*Solomon Islands*,

New Hebrides, *New Caledonia*, *Fiji*, *Friendly*, Samoa or *Navigators*, *Cook's*, *Society*, and *Marquesas* Islands, and the *Low Archipelago*. Off the coast of Ecuador we have the *Galapagos Islands*, under the equator; *Juan Fernandez*, off Chili; *Chiloe* and other islands, included in the *Patagonian Archipelago*, along the western coasts of Patagonia; and the western islands of Tierra del Fuego. Of the smaller islands, the only one worthy of notice is *Antipodes Island*, so called on account of its being nearly antipodal to the British Isles.

The Pacific—its Seas, Bays, Gulfs, Straits, and Channels.

218. A characteristic feature of the Pacific Ocean is the series of gulfs and seas on its western side, partly enclosed by a line of islands from Alaska to Australia, and the almost entire absence of any considerable indentation, except the Gulf of California, on its eastern shores. But there are nowhere any true inland seas like the Mediterranean or the Baltic. In the extreme north we have *Behring's Sea*, bounded on the south by the Aleutian Islands; the *Sea of Okhotsk*, separated from the ocean by the peninsula of Kamtchatka and the Kurile Islands; the *Sea of Japan*, with the Gulf of Tartary, between Saghalien, the Japan Isles, and Corea and Manchooria; the *Yellow Sea*, with the *Gulfs of Pe-che-lee* and *Leao-tong;* the *China Sea*, with the *Gulfs of Tonquin* and *Siam*, between the Indo-Chinese Peninsula and the Philippines and Borneo; the *Sulu*, *Celebes*, *Banda*, *Flores*, and *Java Seas*, between the islands of the Malay Archipelago; the *Coral Sea*, off the north-east of Australia; a few unimportant bays and ports on the eastern coasts of Australia; and the *Gulf of Hauraki*, *Bay of Plenty*, and *Pegasus Bay*, in New Zealand.

219. The western side of the Pacific is, as we have already stated, almost destitute of inlets, the only considerable in-

dentations being the *Gulf of California*, *Bay of Panama*, and the minor *Gulf of Guayaquil*.

220. The principal Straits and Channels are *Behring's Strait*, leading into the Arctic; *Straits of La Perouse*, *Sangar*, and *Corea*, connecting the Sea of Japan with the ocean; the *Strait* and *Channel of Formosa*, connecting the China Sea and the Pacific; the *Strait of Macassar*, between Borneo and Celebes; the *Molucca Pass*, between Celebes and Gilolo; *Torres Strait*, between New Guinea and Australia; *Bass Strait*, between Tasmania and Victoria; and *Cook Strait*, between North and South Islands of New Zealand. On the American coast we have *Queen Charlotte Sound*, *Gulf of Georgia*, and *Strait of Juan de Fuca*, between Vancouver Island and the mainland; and the *Straits of Magellan*, and other channels of Tierra del Fuego, leading into the Atlantic.

221. The Pacific thus communicates with the *Arctic Ocean* by Behring's Strait; with the *Antarctic* by an uninterrupted expanse from Balleny Islands to Graham Land; with the *Atlantic* by Magellan and other straits of Tierra del Fuego, as well as by the open sea between Cape Horn and South Shetland, and may, probably at no distant date, communicate directly by a ship canal across the Isthmus of Panama; under very favourable conditions, vessels might be able to proceed from the Atlantic to the Pacific by the North-West Passage up Davis Strait, thence through Barrow Strait, Melville Sound, Arctic Ocean, and Behring's Strait, or by the North-East Passage round the north of Asia and through Behring's Strait. Several channels and seas between the islands of the Malay Archipelago admit vessels from the Pacific into the *Indian Ocean*, the principal being the Straits of Malacca and Sunda, leading into the Java and China Seas, and thence by the Strait of Macassar, Celebes Sea, and the Channel or Strait of Formosa, into the Pacific; Torres Strait, connecting the Coral Sea of the Pacific with the Arafura Sea of the Indian Ocean.

The Pacific.—General Character of its Coasts.

222. As will be seen from an examination of the accompanying map, the coast-line of the Pacific is on the whole very little indented. Its eastern shores are, with the exception of the Gulf of California, regular and unbroken; its western coast is more broken, forming several considerable peninsulas and gulfs. From Tierra del Fuego to Valdivia, in the south of Chili, the islands of the Patagonian Archipelago fringe the coast, and seem like "fragments detached from the Andes;" their seaward sides being generally high and rocky. The coasts of Chili and Peru are on the whole steep and rugged, but with occasional low sandy beaches. The whole western coast of America as far as Costa Rica preserves a general parallelism to the lofty range of the Andes, which are nowhere far from the sea. With the single exception of the Gulf of Guayaquil, there are no inlets of any magnitude, and but few good harbours. Both Chili and Peru are subject to most violent volcanic disturbances. Lima in 1746, and Concepcion in 1835, were almost destroyed by earthquakes. The Pacific coast of Central America is generally steep, but that of Mexico is low and unhealthy. The *Gulf of California* is the only considerable inlet on the western coast of the American continent; thence north to Vancouver the coast is generally high and unindented, the Bay of St. Francisco being the largest, and commercially the most important. From Vancouver to 60° N. lat. the coast is broken, and fringed by numerous islands, several of them of large size. Thence to the extreme point of the Alaska peninsula the coast is generally bold and rugged; but from Bristol Bay to Kotzebue Sound it is low and swampy, irregular, and considerably indented.

223. The irregular configuration of the eastern coast of Asia, and the line of islands skirting it, have been already noticed. The enclosed seas of Behring, Okhotsk, Japan, and China, are

generally shallow; but, contrary to the general law of depth, the coasts are on the whole lofty, except at the mouths of the larger rivers. A characteristic feature of this coast is the occurrence of three large peninsulas, all trending in the same general direction—viz., those of Kamtchatka, Corea, and Malacca. The east coast of Australia being skirted by continuous and moderately lofty ridges, have their steep slope towards the Pacific, and is therefore generally rugged and unbroken. The *Great Barrier Reef* extends for upwards of a thousand miles along this coast, at a distance varying from sixty to one hundred miles. The coast itself is generally regular and unbroken, but with a few inlets that form good harbours, such as Moreton Bay and Port Jackson.[1]

The Pacific—its River-Systems.

224. Although the area of the Pacific is nearly twice that of the Atlantic, the *drainage area* of the latter ocean is $2\frac{1}{4}$ times greater than that of the former, consequently a much smaller number of rivers discharge their waters into the Pacific. This is due to the relief of the continental land-masses, which encompass the Pacific almost continuously on three sides, but more especially the American and Australian continents. In South America, the chain of the Andes skirts the coast in unbroken ridges from Patagonia to Panama, at a distance from the coast of from 20 to 80 miles. The steep narrow seaboard of western South America, therefore, admits only of the formation of small rivers—mere mountain-torrents, in fact. The northerly prolongation of the Andes, from Panama to the Gulf of California, exhibits the same persistent approximation to the Pacific coast, and consequent absence of any considerable rivers. Further north a minor range still skirts the coast closely, but it is broken in several places to

[1] Port Jackson is one of the finest harbours in the world.

admit of the passage of several streams of considerable size flowing from the more elevated Rocky Mountains—the northern prolongation of the Andes and Mexican Sierras. In the extreme north the continent juts out in the peninsula of Alaska, while the main mountain range continues its northerly trend unchanged; and, consequently, here the extended area of development results in the formation of the longest river of Western America, the Yukon, which has a course of 2,000 miles.

225. In contrast to the mountain-skirted American coast is the eastern, or Pacific, shores of Asia. The sources of the rivers falling into the Pacific are far inland, among the chains that buttress the great central plateau of Asia, so that there is not only a long slope, but also a large and unfailing supply of water. We thus find that the Asiatic section of the Pacific river-system is by far the most important, both in the number and magnitude of its rivers. The Amoor, Hwang-ho, Yang-tze-Kiang, Choo-Kiang, and Mekong are, both in volume and length, not inferior to the rivers of Europe or America. But notwithstanding these important accessions, the river-system of the Pacific, as a whole, is inferior to that of the Atlantic. The drainage area of the latter is estimated at 19,050,000 square miles, while that of the Pacific is only 8,460,000 square miles, or about $2\frac{1}{4}$ times less.

226. Our limits do not allow of any extended description of each river, nor does it properly come within the scope of this work to do so; and we must therefore refer the student to the "Geography of River-Systems," published by Messrs. Philip & Son. The following table shows the locality, length, and area of drainage of the principal rivers flowing into the Pacific :—

THE PACIFIC RIVER-SYSTEM.

Section.	River.	Draining.	Length Miles.	Area of Drainage. Sq miles
N. AMERICAN SECTION.	Yukon	Alaska	2000	—
	Fraser	British Columbia	600	98,000
	Columbia	British Columbia, and United States	750	265,000
	Sacramento	United States	420	63,000
	Colorado	„	1100	230,000
S. AMERICAN SECTION.	Bioblo	Chile	180	—
	Maypu	„	160	—
ASIATIC SECTION.	Amoor	Siberia	2300	900,000
	Pei-ho	China	250	—
	Hwang-ho	„	2600	400,000
	Yang-tze-Kiang	„	3200	760,000
	Choo-Kiang	„	1100	—
	Maykiang, or Mekong	Anam, Cambodia	1600	216,000
	Menam	Siam	900	
AUSTRALIAN SECTION.	Shoalhaven	New South Wales	260	3,300
	Hawkesburg	„	330	8,700
	Hunter	„	300	7,900
	Manning	„	100	3,000
	McLeay	„	190	4,800
	Clarence	„	240	8,000
	Brisbane	Queensland	130	5,400

THE PACIFIC—ITS CURRENTS.

227. Owing to its immense area, and the frequent intervention of islands and reefs, the currents of the Pacific are more complicated than those of the Atlantic, and are not so well

known, the main streams only having been satisfactorily investigated. Being almost land-locked on the north, the currents of this ocean must derive their initial impulse from the Southern Ocean, into which it opens broadly. From the belt of water that circles the globe between lat. 50° and 70° S., a northerly surface-drift sets into the three great oceans, in obedience to the general law of oceanic circulation. The northerly surface-drift of the Antarctic and South Pacific, as it advances into areas having a higher velocity of rotation, is deflected more and more to the eastward, and off the Chilian coast divides into two main streams—one bearing away eastwardly round Cape Horn into the Atlantic, known as the *Cape Horn current*, while the other curves north, skirting the coasts of Chili and Peru as the *Peruvian current.*[1] This current is necessarily characterized by a much lower temperature than the ocean in the same latitudes—the difference off Lima being as much as 20° F. It then turns to the west, and merges in the southern branch of the great *Equatorial current* of the Pacific, the northern and southern branches of which hold on due west across the Pacific towards the East Indian Archipelago, but are separated by the *Equatorial Counter-current*, flowing in an exactly opposite direction. Several minor streams seem to press through the numerons streams and channels between the islands of Malaysia into the Indian Ocean, but the main portions of both the North and South Equatorial currents have definite prolongations,—the former to the south as the *East Australian current*, the latter to the north as the *Japan current.* Of the East Australian, or, as it is sometimes called, the New South Wales current, it will suffice to note that, after skirting the coast of New South Wales, it turns east, and then north-east along the western coast of New Zealand, and finally merges into the general north-easterly drift from the Antarctic Ocean.

[1] Sometimes called *Humboldt's current*.

228. The North Equatorial current of the Pacific pours its waters into the deep basin[1] lying between the Ladrones and the Philippines, and the Pelew Islands and Japan. Thence issues a powerful, warm, and rapid current, the well-known Japan Current, or *Kuro-Siwo*.[2] Bending round the eastern coasts of Japan, this current, in lat. 40° N., bifurcates, a minor drift setting north along the Kurile Islands and Kamtchatka into Behring's Sea, and thence through Behring's Strait into the Arctic Ocean. But the main portion sweeps along the Aleutian Islands, Alaska, and British Columbia, and then curves south, finally merging into the northern branch of the Equatorial current, having sent a minor branch along the shores of California and Mexico, forming the periodical *Mexican current*. A branch of the Japan current also sweeps through the Straits of Corea into the Sea of Japan, and probably another may find its way between the Kurile Islands into the Sea of Okhotsk. In the latter, however, and even as far south as the China Sea, there is a southerly drift of cold water from Behring's Sea. Even this slight sketch of the "Kuro-Siwo," or Japan current, will show that it is almost a counterpart of the Gulf Stream in the Atlantic, and that it forms, in fact, the "Gulf Stream of the Pacific." The deep basin whence it flows is a modified counterpart of the Caribbean Sea and the Mexican Gulf, and the general north-easterly direction agrees exactly with that of the Gulf Stream. The influence of the two currents on the coasts towards which they flow is similarly shown in the perfectly open waters, all the year round, of British Columbia and Western Europe. Both currents are similarly flanked on their landward side by a narrow cold current flowing in an exactly opposite direction, and finally sinking below them as under-currents.

[1] Named the "Sea of Magallanes" by Mr. Wild, in honour of the first European who crossed the Pacific.

[2] *i.e.*, Black Stream, so called from the deep-blue colour of its water, which contrasts strongly with the muddy water of the Yellow Sea.

[Mr. J. J. Wild, Member of the Civilian scientific staff of H.M.S. *Challenger*, thus eloquently contrasts[1] the Gulf Stream of the Atlantic and the Japan Current of the Pacific:—"No two natural phenomena could present a more complete parallelism than that which can be traced between the origin, progress, and ultimate fate of the great thermal currents of the North Atlantic and North Pacific Oceans. It constitutes one of the most remarkable proofs of the uniformity of laws and conditions which determine the movements of the oceanic waters from pole to pole. The pouring in of the North Pacific Equatorial current through the chain of islands which separates the Sea of Magallanes from the main basin of the Pacific, just as the North Atlantic Equatorial current flows into the Caribbean Sea through the Antilles—the progress of the Pacific current through the southern portion of the Sea of Magallanes, and the accumulation of its waters in the northern and more restricted portion of this sea, as we observe the circulation of the Atlantic current through the Caribbean Sea, and the accumulation of its waters in the Gulf of Mexico—the relief of the pressure caused by this accumulation, through the formation in both cases of a powerful current, which forces its way through the northern end of the barrier of islands, and joins the branch of the Equatorial current, which has been moving northwards outside this barrier—finally, the sub-division of both Equatorial currents, after their encounter with the Polar currents, into branches, some of which continue their course into the Polar Seas, while others bend round, and, gradually cooling in contact with the currents from the north, flow down the western coasts of the opposite continents, in order to resume once more their course in the character of equatorial currents,—form two parallel series of occurrences, the resemblance between which is too close to be the result of mere accident."]

229. There are several other minor and but partially known currents in the vast expanse of the North Atlantic, encircled by the Equatorial and Japan currents. These minor currents appear to have a generally easterly drift, but complicated and uncertain, and are probably caused by numerous obstructions

[1] See his admirable essay, *Thalassa* (Marcus Ward), a work which should be found in the library of every teacher of geography.

to the main westerly set of the surface water. One high authority[1] thinks they are the results of shallows in that region. The numerous reefs, islands, sub-marine ridges, and prevailing and periodical winds, all no doubt combine to produce a most complicated minor system of currents in the great whirl of the North Pacific. The Mexican and Okhotsk currents are undoubtedly produced by the winds alone, for they change their direction in accordance with the prevailing winds—the former running north-east in summer, and south-east in winter, while the latter varies from east to west, according to the prevalent winds. In the South Pacific the most important minor stream is called *Mentor's current*, and is in reality the South Equatorial counter-current.

THE PACIFIC—ITS DEPTH, AND CONFIGURATION OF ITS BED.

230. The Pacific Ocean has not, for obvious reasons, been so minutely explored as the Atlantic, and was formerly supposed to be, on the whole, inferior in depth to the latter ocean. The recent observations of the *Challenger*, *Gazelle*, and *Tuscarora*, however, proved that this supposition is incorrect, and that, notwithstanding the immense number of islands scattered over the Western Pacific, the general depth of that ocean is fully equal to, if not exceeding, that of the Atlantic. The greatest known depth in the Atlantic is 3875 fathoms, but in the Pacific the *Tuscarora* obtained several soundings over 4000 fathoms; the *greatest depth*, however, was found by the *Challenger* in 1875, between the Carolines and the Ladrones, in 11° 24′ N. lat., and 143° 16′ E. long., where a sounding of 4575 fathoms, or about 5¼ miles, was obtained.

231. As regards the configuration of its bottom, the Pacific may be broadly divided into four basins, the limits of which may be roughly marked as follows: (1) The *North-Eastern* basin, limited on the north by Kamtchatka, Aleutian Isles, and Alaska,

[1] Sir J. Herschel.

and on the east by the American coast from Alaska to Chili. A line drawn from Japan to the Sandwich Islands, and thence by the Marquesas, Gambier Island, Easter Island, Juan Fernandez, to Chili, forms the western and southern limits of this basin, distinguished from all the other basins by an almost entire absence of islands, the only groups at any distance from the coast being the Galapagos and Revillagigedo Islands. Along its western limits a depth of 3000 fathoms is frequently attained; while in its northern portion, off Japan, a depth of over 4000 fathoms has been found. (2) The *Southern* basin of the Pacific may be said to extend from the limit of drift ice on the south, to the submarine ridge which divides it from the north-eastern basin. On the north are two unequal "bights," a minor elongated one between East Australia and New Zealand, and a wider bight, bounded by a line of islands—New Zealand, Friendly, Cook, Austral, Easter, and Juan Fernandez. The ridge of which these islands are the summits unites broadly with the coasts of Chili and Patagonia. In its deeper parts, this plateau does not seem to be depressed lower than about 1,500 fathoms below the surface, and the general depth of the basin it encloses is about 2000 fathoms. (3) What may be termed the *Central* basin is indeed but a westerly prolongation of the North-Eastern basin, and is bounded on the west by a chain of islands from Kamtchatka, by Japan. Ladrones, Carolines, Marshall, and Feejee Islands, to New Zealand. This basin, although studded with numerous islands, is yet of a much greater average depth than either of the other basins which it subjoins—a large portion having an average depth of 3000 fathoms. But perhaps the most marked of all the Pacific basins is (4) the *Western* basin, lying between the chain of islands just mentioned and the eastern coasts of Asia, and consisting for the most part of shallow and nearly land-locked basins, such as the Seas of Okhotsk, Japan, Yellow and China, and the numerous seas of the

Malay Archipelago. One portion of this basin, however—that of the Sea of Magallanes, lying between the Benin, Ladrone, and Caroline Islands on the east, and the Philippines on the west, and extending meridionally from Pelew Islands to Japan—is not inferior in depth to any of the other great basins, its average depth being about 3,000 fathoms. This basin is important, as being to the Pacific what the Caribbean Sea and the Gulf of Mexico are to the Atlantic—the *cul de sac* whence issues the great thermal current of the Pacific—a current which, although its climatical influence is not so well marked as its counterpart in the Atlantic, is yet by far the most important in the "Grand Ocean."

The Pacific—its Navigation and Commerce.

232. The fine weather that favoured Magellan in his voyage across the Pacific, and induced him to designate the newly-discovered sea "Oceano Pacifico," is not by any means characteristic of this ocean. Frequently terrific storms sweep over its broad expanse, and this, together with an imperfectly-known and complicated system of currents, and the numerous reefs and shallows, combine to make its navigation difficult. The most frequented routes are—(1) from San Francisco to China and Japan, by way of the Sandwich Islands; (2) round Cape Horn to the Pacific ports of America, from Concepcion to San Francisco; (3) from Panama to Australia; and (4) the homeward route from Australia and New Zealand, south of the fiftieth parallel, and round Cape Horn into the Atlantic. A vast trade is also carried on by England, the United States, &c., with the numerous fertile and productive islands scattered over the Pacific. The following table shows the principal articles exported from, and imported by, the various countries bordering on the shores of the Pacific:—

233. COMMERCE OF PACIFIC MARITIME STATES.

**** *The numbers given in this list are taken from the latest official returns.*

1	2	3	4	5	6	7	8
Country.	Principal Imports.	Total Value.	Principal Exports.	Total Value.	Principal Ports.	Value of Imports from Gt. Britain & Ireland.	Value of Exports to Gt. Britain & Ireland.
		£		£		£	£
Alaska (belonging to U. States) ...	—	—	Timber, furs.	—	Sitka, or New Archangel.	—	—
British Columbia and Vancouver ..	Manufactured goods and colonial produce.	—	Gold, coal, timber.	—	Victoria, New Westminster.	—	—
United States (Pacific States and Territories).	Do.	—	Gold, silver, wheat, fruits, timber, &c.	—	San Francisco.	—	—
Mexico	See page			—	Mazatlan, Acapulco.	—	—
Guatemala.....	Chiefly textile fabrics.	550,000	Indigo, coffee, cochineal, &c.	754,637	Istapa.	—	—
San Salvador.....	Do.	390,000	Indigo, &c.	737,000	La Union.	—	—
Nicaragua	Unimportant.	—	—	—		—	—

COMMERCE OF PACIFIC MARITIME STATES.—*(Continued.)*

1	2	3	4	5	6	7	8
		£		£		£	£
Costa Rica	Manufactured goods.	521,740	Chiefly coffee.	681,891	Punta Arenas.	—	—
Colombia	Manufactured goods.	1,465,785	Cocoa, tobacco, coffee, Peruvian bark, dyes, hides.	2,895,579	Panama, Cupica (Cartagena).	1,031,952	932,936
Ecuador					Guayaquil.	200,111	299,784
Peru	Cotton, woollen, and other goods.	—	Guano, saltpetre, sugar, silver, copper, Peruvian bark, wool.	—	Arica, Cal'ao, Truxillo.	1,369,831	5,232,305
Bolivia.....	Manufactured goods.	1,100,000	Peruvian bark, coffee, cocoa, silver, copper, tin, nitre, guano.	900,000	Cobija.	73,395	601,026
Chili.....	Cotton and woollen goods, iron, cocoa, coffee, sugar.	29,212,764	Copper, silver, wool.	5,943,474	Valparaiso, Coquimbo.	1,501,400	3,279,808
Siberia.....	—	—	Chiefly furs.	—	Okhotsk, Petropaulovski.	—	—
Japan	Cotton and woollen goods, iron, wrought and unwrought.	About 4,000,000	Tea, raw silk, rice, tobacco.	About 4,000,000	Kanagawa (Yokohama), Nagasaki, Hiogo, Hakodate, Yedo (Tokio).	2,615,616	628,805

COMMERCE OF PACIFIC MARITIME STATES.—*(Continued.)*

1	2	3	4	5	6	7	8
China.....	Cotton and woollen goods, opium.	£ 21,376,572	Tea, raw silk, porcelain.	£ 20,151,654	Canton, Amoy, Shang-hai.	£ 3,738,125	£ 13,600,000
Malay Archipelago	Manufactured goods, opium.	—	Sugar, coffee, pepper, tobacco, spices, tea, indigo, gold, edible birds' nests.	—	Singapore (Batavia, Samarang, Bencoolen.)	—	—
Queensland	Cotton, woollen, and linen goods, apparel and haberdashery, hardware and iron, sugar, tea, coffee, &c., timber, coals, wines, and spirits.	£ 3,201,665	Wool, preserved meat, copper.	£ 3,615,785	Brisbane, Port Curtis.	£ 916,757	£ 999,261
New South Wales		14,768,873	Wool, tin, copper, tallow, hides, preserved meat, gold.	12,965,879	Sydney, Port Macquarie, Newcastle.	6,242,111	4,463,142
Tasmania		1,324,812	Wool, corn, flour, timber, tin, gold.	1,315,695	Hobart Town, Launceston.	262,953	501,113
New Zealand...		8,755,663	Wool, gold, timber, provisions, kauri, gum, corn and flour, preserved meat.	6,015,525	Auckland, Wellington, Dunedin, Nelson.	4,314,004	4,017,525

234. Of the numerous islands scattered over the Pacific, the following are commercially the most important:—The *Sandwich Islands*, on the route between North America and China, producing coffee, sugar, arrowroot, cotton, &c.; chief port, Honolulu. The *Ladrone*, *Caroline*, *Marshall*, and *Pelew Islands* produce sugar, indigo, cotton, rice, &c.; the *Fiji*, or *Viti Islands*, producing fruits, bread fruit, banana, sugar, tobacco, coffee, &c.; the *Friendly Islands*, exporting chiefly cocoa-nut oil; *Samoa* or *Navigator's*, *Society*, *Cook*, *Austral*, *Gambier Islands*, and the *Low Archipelago* and *Marquesas*, largely export cocoa-nut oil, sugar, arrowroot, fine fruits, &c.; *Queen Charlotte Islands*, *New Britain*, *New Hebrides*, *Admiralty*, and *Arao Islands*, and *New Guinea*, have similar productions, and also export birds of paradise, tortoise-shell, pearls, gold, spices, sago, &c.

The Pacific.—Historical Notes.

235. Both the Atlantic and Indian Oceans were partially known at a very early period to the adventurous voyagers of Phœnicia, but for hundreds of years after the decline of their extensive commerce, the great nations that dwelt on the borders of the Mediterranean knew nothing of the vast expanse of the Pacific, which seems to have been first approached from Europe by land, by missionaries to China or Cathay. An Arab merchant, Sulaiman, in the middle of the ninth century, first reached *China* by sea. It was not until 1291 that an European, Marco Polo, crossed the China Sea and sailed through the Straits of Malacca into the Indian Ocean. Four years later he returned to Europe and published an account of his travels, upon which several European travellers set out for the East, and thus the western shores of the Pacific were gradually explored early in the fourteenth century, nearly 200 years before its eastern shores were first seen by Balbao from the highlands of Panama, or Magellan entered it from the Atlantic through the straits that still

bear his name. Vasco de Gama opened the way for the exploration of the western Pacific when in 1497 he doubled the Cape of Good Hope, and sailed across the Indian Ocean to *Calicut*. Early in the sixteenth century the great Albuquerque extended the Portuguese settlements beyond Malacca, and established commercial relations with the *Sunda Islands* and even *China* on the north, and *New Guinea* on the south. Balbao had, in 1513, gazed on the vast expanse of the eastern Pacific from the heights of Panama at about the same time that Serrão, or Serrano, coasted the great ocean beyond the *Moluccas* or Spice Islands on the west. As the Portuguese fleets commanded the route round the Cape of Good Hope, Magellan determined to open up for the vessels of Spain another route round Cape Horn. With that view he sailed from Spain with five ships in 1519, and in October in the following year he passed through the channel now called after him, Magellan Straits, and sailed boldly across the unknown expanse of the "Oceano Pacifico," and finally sighted the *Ladrones*. Pressing on, he reached the Philippines in April 1521, where he was murdered. The expedition, however, reached the Moluccas, and in September 1522 the few survivors in the "Vittoria" landed on the coast of Spain, being thus the first to circumnavigate the globe.

236. The conquest of Mexico by Cortes was speedily followed by the exploration of the western shores of America, and Spanish vessels sailed along the coast from *California* to *Peru*, which ultimately led to the conquest of the latter country—then the nucleus of the extensive empire of the Incas—by a band of adventurers under Pizarro. While the Spaniards were thus engaged in reducing the native states of Central and South America under their sway, the Portuguese were extending their commerce to *China*, *Japan*, and contiguous islands. The increasing importance of the East Indian trade stimulated further research for independent routes to the

Pacific from Europe; and as Magellan's route, by way of Cape Horn, was very long, European navigators turned their attention to the north, and thus commenced that long-futile series of expeditions to discover either a *north-east passage* round the north coast of Asia, or a *north-west passage* through the Archipelago north of North America. Particulars of the various attempts made in both these directions will be given in the historical notice of the Arctic Ocean, so that we shall not dwell on them here.

237. The English admiral, Drake, having seen the Pacific, like Balbao, from the mountains of Panama, resolved to sail upon it, and in 1577 his squadron was busy destroying and plundering the Spanish settlements from *Chili* to *Mexico*. Drake appears to have sailed as far north as the modern *San Francisco*, whence he crossed the ocean to the Spice Islands, and thence sailed home by way of the Cape of Good Hope. The Pacific began now to be more thoroughly explored, and one by one the great island groups scattered over its broad expanse were discovered and named. Thus Mendana, in 1567, discovered the islands which he named *Solomon Islands;* and in the year following the *Marquesas* were first seen. At the end of the sixteenth century the northern coast of *Australia* became known, and in the years 1619-1627 the eastern and western coasts of the island-continent were explored by Dutch navigators; and in 1642 Tasman discovered *Van Dieman's Land*—since called Tasmania—and New Zealand. In 1686, *Easter Island* was discovered by Roggewein; and, thirteen years later, the island of *New Britain*, and the straits which separate it from *New Guinea*, were explored by Dampier. On the north, Behring explored the strait that bears his name, and discovered the chain of the *Aleutian Islands*. Anson's expedition to the Pacific, in 1739, resulted in the discovery of several small islands; and Vancouver, in 1791, found the island now called after him.

238. Of all the navigators of the eighteenth century, the greatest addition to a thorough knowledge of the Pacific

and its islands resulted from the famous voyages of Captain Cook. Having coasted New Zealand in 1769, he sailed north-west, and explored the eastern coast of Australia, which he named New South Wales. Passing through Torres Strait, between Australia and New Guinea, he returned home round the Cape of Good Hope. His second voyage was mainly devoted to the exploration of the great Southern Ocean. In 1776 he set out again to find a north-west passage from the Atlantic into the Pacific by Behring's Strait. He attempted this *from* the Pacific, but after succeeding in entering the Arctic through Behring's Strait, he could not penetrate further than Icy Cape. On his way home he explored the Sandwich Islands, and was there murdered by the natives in 1779. Another attempt to discover a north-west passage by Behring's Strait was made in 1785 by La Perouse, and indirectly resulted in an examination of the *Islands of Japan* and *Saghalien*, the strait between which was named after him. In 1797 Mr. Bass coasted the Australian shores in an open boat from Port Jackson; and two years later Flinders circumnavigated Tasmania, and named the channel between that island and Australia after Mr. Bass. The discovery of *New South Shetland* in 1816, by Captain Smith, of the brig "William," bound for Valparaiso, completed actual discovery in the Pacific; the subsequent discoveries further south by Balleny and others will be noticed in connection with the Antarctic Ocean. The necessities of a constantly increasing commerce rapidly led up to a careful examination of the more frequented routes; the numerous reefs were specially investigated, as being the most dangerous element in the navigation of the Pacific. Recently the great "South Sea" has been scientifically explored by the *Challenger*, the *Gazelle*, the *Tuscarora*, and other vessels. The course of the *Challenger* in the Pacific may be roughly marked by lines joining the following places: Melbourne, New Zealand, Friendly Islands, Torres Strait, Hong Kong, Admiralty Islands, Japan, Sandwich Islands, Tahiti, Valparaiso, and Magellan Straits.

III.

THE INDIAN OCEAN.

The Indian Ocean.—Boundaries and Extent.

239. The Indian Ocean is distinguished from the Atlantic and Pacific Oceans by not only a much smaller area, but also by the fact that it alone of the three great oceans is entirely separated from the North Polar Basin. Both the Atlantic and Pacific communicate with the Arctic Ocean—the former freely by two large channels; the latter by the narrow strait of Behring. But between the Indian Ocean and the Arctic Sea there intervenes the vast continent of Asia, stretching south, meeting the northern limits of the waters of this ocean only twenty degrees north of the equator. Unlike the North Atlantic and North Pacific, the North Indian Ocean is restricted in area, and, consequently, the vast thermal currents and other physical features that distinguish the other oceans north of the equator are wanting. South of the equator, however, the Indian Ocean, like the Atlantic and Pacific, opens out broadly into the unknown ice-bound expanse within the Antarctic Circle. Bounded on the north by Asia, on the west by Africa, and on the east by Malaysia and Australia, its limits on the south are partly natural—such as Clarie, Sabrina, Kemp, and Enderby, Lands—and partly imaginary, along the Antarctic Circle. South of Cape Agulhas, the southernmost point of the African continent, the boundary between the Indian and Atlantic Oceans is an imaginary line drawn

PERSIA
ARABIA
INDIA
CHINA
Mediterranean
EGYPT
Tropic of Cancer
Red Sea
Aden
Arabian Sea
Bombay
Calcutta
Bay of Bengal
Madras
Ceylon
Andaman Is.
Nicobar Is.
Siam
China Sea
Singapore
Borneo
Java
Maldives
Laccadives
Guardafui
Seychelles Is.
Amirante Is.
Victoria
Mozambique
Zambesi
Sofala
Port Luke
Mauritius
Reunion
Tropic of Capricorn
Keeling or Cocos Is.
N.W. Cape
Sharks B.
WEST AUSTRALIA
Perth
Albany
Natal
Durban
Cape Colony
Port Elizabeth
Agulhas
OCEAN
INDIAN
AFRICA
ATLANTIC OCEAN
New Amsterdam
St. Paul's
Crozet Is.
Prince Edward Is.
Kerguelens I.
M.Donald Is.
Antarctic Circle
Kemp I.
Enderby I.
ANTARCTIC OCEAN
30
60
90
120
THE INDIAN OCEAN
on Mercators Projection

from that cape along the meridian of 20° E. long. to the Antarctic Circle. Similarly, the boundary on the east, south of Tasmania, is also theoretical, the meridian of South-West Cape in that island being taken as the limit between the Indian and Pacific Oceans. The meridional distance from the coast of Beloochistan, on the north, to Kemp Land, on the south, is about 6,300 miles; under the equator this ocean extends uninterruptedly for nearly 4,000 miles, and further south, between Shark Bay on the east, and Delagoa Bay on the west, more than 5,000 miles. Still further south we have an *extreme breadth* of upwards of 6,000 miles from Cape Agulhas to Tasmania. Its *area* has been variously estimated at from 17,000,000 to 25,000,000 square miles; one eminent geographer estimates it at 29,219,000 square miles. If we take a line from Cape Agulhas to Cape Leeuwin as the southern boundary of the Indian Ocean, its shape might be described in general terms as approximating to an equilateral triangle; its apex being intersected by the great, wedge-like promontory of Hindostan, the western coasts of which are opposite to those of Arabia; its eastern shores being opposite to those of Further India. South of the parallel of 10° N. lat. we have—

On the West.		On the East.
Ajan and Zanzibar	opposite to	Malay Peninsula, Sumatra, Java, &c.
Mozambique, Sofala, Sabia (with Madagascar).	"	Australia, from Port Essington to Shark Bay.
Natal, Kaffraria, Cape Colony (East).....		West Australia.

The Indian Ocean.—Seas, Bays, Gulfs, Channels, and Straits.

240. Of the various *inlets* of the Indian Ocean, two only, the Red Sea and Persian Gulf, are, strictly speaking, inland seas. The extension north of 10° N. lat., between Arabia and the west coast of India, is known as the Arabian Sea,

and that between the east of India and Further India as the Bay of Bengal. With the Arabian Sea are connected the *Gulfs of Cambay* and *Cutch*; the *Gulf of Oman*, connected by the Straits of Ormuz with the Persian Gulf; the *Gulf of Aden*, connected by the Straits of Babel-mandeb with the Red Sea. The African coast from Cape Guardafui to Cape Agulhas is singularly regular and unbroken; of the few small inlets the only noticeable one is the fine natural harbour of *Delagoa Bay*. Passing over the seas of Malaysia as bordering on, rather than belonging to, the Indian Ocean, we come to the island-continent of Australia, on the north of which we have the *Gulfs of Carpentaria*, *Van Diemen*, and *Cambridge*, and on the west are numerous small inlets, of which the principal are *Exmouth Bay*, *Shark Bay*, and *Geographie Bay*. On the south we have the Great Australian Bight, with the *Gulfs of Spencer* and *St. Vincent*, *Encounter Bay*, *Portland Bay*, and *Port Philip*.

241. Of the *straits* and *channels* connecting the Indian Ocean with its minor seas and other oceans, the principal are the Straits of Babel-mandeb, connecting the Red Sea and Gulf of Aden; the Straits of Ormuz, connecting the Persian Gulf and Gulf of Oman; the Straits of Malacca and Sunda, connecting the Indian Ocean and China Sea; Torres Strait, between the Arafura and Coral Seas; and Bass Strait, between Australia and Tasmania. The Indian Ocean communicates freely with the *Antarctic Ocean*, and is also conterminous with the *Atlantic* south of Cape Agulhas for $31\frac{1}{2}$ degrees, and with the *Pacific* south of Tasmania for 23 degrees of latitude. But vessels may now proceed from the Atlantic to the Indian Ocean without doubling the Cape of Good Hope, *i.e.*, by the Mediterranean, *Suez Canal*, Red Sea, and Gulf of Aden. The great channels of communication between the Indian and Pacific Oceans are the Straits of Malacca, opening directly into the China Sea; the Strait of Sunda, leading into the Java Sea, and thence into the China Sea; or by the Strait

of Macassar into the Pacific; the channels between Java, Lombok, Sumbawa, Flores, Timor; and the Arafura Sea, Torres Strait, between Papua and Northern Australia. Between Ceylon and the mainland of India is the narrow and shallow Palk's Strait, and between Madagascar and the African coast is the wide Channel of Mozambique.

242. Of the *islands* actually within the Indian Ocean, the principal are:—Madagascar, off the African coast, and the neighbouring smaller islands of Bourbon, Mauritius, Rodrigue, Amirante, Seychelles, and Comoro; Zanzibar Island and Socotra; Chagos, Maldives, Laccadives; Ceylon, Andaman, Nicobar, and Mergui Islands; Sumatra, Java, Lombok, Sumbawa, Sandalwood, Flores, Timor; Groote Eylandt, Melville Island, and Tasmania, off Australia; and the islets of St. Paul, Amsterdam, Kerguelen, Crozet, Marion, and Prince Edward, in the open ocean on the south.

The River-system of the Indian Ocean.

243. Bounded as the Indian Ocean is on three sides by Africa, Asia, and Australia, its river-system is naturally divisible into three sections—the African, Asiatic, and Australian.

244. Of the *African section* it will suffice to remark that the central equatorial regions are drained by the Nile into the Mediterranean, and that, consequently, there is no area for the development of any large rivers east of the Nile basin. With the exception of the Gananeh, Shebeyli, and Rovuma, the streams that drain the easterly slope of the central plateaux of Africa are unimportant. Further south, however, we have the two large rivers of the Zambesi and Limpopo. From Delagoa Bay to Cape Agulhas, a considerable number of streams drain the counter-slope of the Drakensberg, and other ranges of South Africa.

245. The *Asiatic section* comprises some of the largest

rivers of the globe, which drain the continent south of the Armenian Mountains, and the table land of Tibet. The Euphrates and Tigris fall into the Persian Gulf; the Indus, Nerbudda, and other rivers of Western India, fall into the Arabian Sea; while the Cauvery, Krishna, Godavery, Mahanuddy, Ganges, Brahmapootra, and other rivers of Eastern Hindostan, and the Martaban, Sitang, and Irrawaddy, draining Further India, fall into the Bay of Bengal.

246. Of the *Australian section* of the river-system of the Indian Ocean, the only large rivers are the Murray and its three principal tributaries—Darling, Lachlan, and Murrumbidjee, draining South-East Australia. The rivers draining the western and northern parts of the continent are of no great length or importance, the principal being the Swan, Murchison, Gascoigne, Victoria, Daly, and Flinders. The following table gives the locality, length, and drainage area of the principal rivers falling into the Indian Ocean :—

247. THE RIVER-SYSTEM OF THE INDIAN OCEAN.

Section.	River.	Draining.	Length	Area of Basin.
			Miles.	Sq. miles.
African Section.	Limpopo	Transvaal, Sofala	800	—
	Sabia	Sofala	300	—
	Zambesi	S. Africa	2400	—
	Rovuma	District east of Lake Nyassa	Nav. for 150	—
	Gananeh	Somauli country	800?	—
	Shebeyli	" "	850?	—
Asiatic Section.	Euphrates	Asia Minor	1700	230,000
	Tigris	" "	1400	
	Indus	India	1700	400,000
	Nerbudda	"	800	35,000
	Tapty	"	440	25,000
	Cuavery	"	470	35,000
	Krishna	"	800	100,000

Section.	River.	District.	Length	Area of Basin.
			Miles.	Sq. Miles.
Asiatic Section.	Godavery	India	900	120,000
	Mahanuddy ...	„	240	75,000
	Ganges	„	1500	420,000
	Brahmapootra..	„	930	—
	Irrawady	„	1200	150,000
Australian Section.	Murray	New South Wales, Victoria, & S. Australia	1200	270,000
	Swan	W. Australia.....	—	—
	Murchison.....	„	800	—
	Gascoyne	„	—	—
	Victoria	—	Nav. 100	—
	Daly	—	—	—
	Flinders.....	—	—	—

The Indian Ocean.—General Character of Coasts, Principal Currents, Depth, and Form of its Basin.

248. From Algoa Bay to Natal the coast is comparatively high, and in parts rocky and entirely destitute of harbours. The ports of Elizabeth and East London are open, exposed bays; while that of Natal is rendered almost useless, except to small vessels, by a dangerous bar right across its entrance. Thence to the magnificent natural harbour of Delagoa Bay the coast is low, and generally fertile. From this inlet to Zanzibar the coast is generally low, swampy in some parts, and extremely fertile in others; but further north, to Cape Guardafui, extends a strip of wild and desert coast. The coast of the Red Sea presents "nothing but precipitous gulleys, barren sands, and inaccessible cliffs." The northern shores of the Indian Ocean are indented by the three peninsulas of Arabia, India, and Malaysia, and contain several good ports. The eastern shores of the Red Sea are rugged and inaccessible, and those of the Arabian Sea are generally precipitous. The

navigation of the Persian Gulf is rendered difficult by numerous coral reefs and islets. South of the Gulfs of Cutch and Cambay, the Malabar coast of India has but few good harbours, that of Bombay being the best. The eastern, or Coromandel coast, is generally low and unbroken, has no harbours, and is exposed to heavy surf; vessels lying off Madras and other towns on the coast anchor in open roadsteads. The northern coasts of Australia are generally low, and not unfertile in some parts. Besides the large inlet called the Gulf of Carpentaria, there are several other smaller bays, which form good natural harbours. From Shark Bay to King George's Sound the coast is somewhat higher, and in parts rocky. Thence eastwards the shores of the great Australian Bight are low, sandy, and barren, except here and there, between Spencer Gulf and Cape Wilson. Both on the south coast of Australia and the island of Tasmania are several inlets, which form excellent harbours.

249. The currents of the Indian Ocean are not so numerous or persistent as those of the larger Pacific and Atlantic Oceans. Being entirely land-locked on the north, and extending scarcely twenty degrees north of the equator, there is no room for the development of such grand currents as the Gulf Stream of the North Atlantic and the Black Stream of the North Pacific. This ocean is, moreover, subject to severe periodical and variable winds. The periodical winds are known as the monsoons, and blow from the north-east for half the year, and from the south-west during the other half.[1] Farther north, in the Arabian Sea and Bay of Bengal, the winds vary their direction according to the position and contour of the regions over which they blow. In the Red Sea the winds "follow the direction of its shores, and blow, for six months of the year, alternately up and down its long trough-like valley, confined and guided in their passage by the

[1] For full explanation of the monsoons, &c., see Hughes's *Physical Geography*, pp. 148-153.

mountain chains which bound it upon either side." Evaporation is also most active,[1] especially in the Red Sea; and precipitation along the southern slopes of the Himalaya is enormous.[2] All these causes—variable and periodical winds, active evaporation and heavy precipitation, and consequent discharge of immense volumes of water by the Ganges, Indus, and other rivers—combine to make the current-system of the North Indian Ocean most complicated and uncertain.

250. South of the equator the case is different. There we have not only a comparatively large area for development, but also an almost uninterrupted communication with the South Polar basin, whence the great current systems of all the great oceans seem to receive their primary impulse. Between the parallels of 40° and 60° there is a general north-easterly "set" of the chilled and iceberg-laden waters from the Antarctic regions. Striking against the western coasts of all the great continents, it divides; its branches flowing north along the western shores of Australia, Africa, and South America, and ultimately merging in the equatorial currents of the Indian, Atlantic, and Pacific Oceans respectively. Off the eastern extremities of the three continents, this *Antarctic Drift*, as it is called, is encountered by warm currents from the equatorial regions of the great oceans—the Agulhas current off South Africa, the Brazilian current off Patagonia, and the East Australian current off Victoria. The low temperature of the Antarctic Drift current is undoubtedly due to its origin, and the continual supply of icy-cold water by the constant liquefaction of enormous icebergs, vast numbers of which float in the Southern Ocean, between 60° and 40° south latitude. In

[1] "Near the coast of India the evaporation from the sea is said to amount to about three-quarters of an inch in the 24 hours, or nearly 23 feet in the year. In the Red Sea, a layer of 28 feet of water is believed to be annually driven off by evaporation." Geikie's *Physical Geography* (Macmillan).

[2] The rainfall on the counter-slope of the Western Ghauts amounts to 260 inches annually, while in the Khasia Hills it ranges from 500 to 600 inches in the year.

all cases the encounter between this cold north-easterly drift and the southerly warm currents from the equator results in the total or nearly entire deflection of the latter to the eastward; that is, excepting those portions which sink and travel in a south-easterly direction towards the South Polar regions as warm under-currents.

251. In the Indian Ocean the Antarctic Drift divides off Cape Leeuwin, one branch holding on to the east, along the south coast of Australia, and meeting off Victoria the East Australian current; the other branch proceeds in a northerly direction nearly parallel to the coast of West Australia, as far as North-West Cape, where it is deflected to the west by the great *South Equatorial current* of the Indian Ocean. This vast constant current sets into the Indian Ocean from the Pacific through the numerous seas and channels of the Malay Archipelago, south of the equator, and sweeps across towards the African coast. Off the Mauritius and the adjoining islands, it bifurcates, the larger portion flowing south along the east coast of Madagascar, while the other pushes through the channels between Cape Amber, the Amirante Islands, and the Seychelles, and, uniting with a drift setting south along the African coast, forms the *Mozambique current*, flowing through the channel of that name between Madagascar and the mainland.[1] Debouching out of this channel with increased power and a velocity of not less than 70 or 80 miles a day, it curves round the coast of South Africa as the well known *Agulhas current*. The continuity of this current is broken by the Agulhas Bank; a minor branch probably doubles the Cape of Good Hope and flows into the Atlantic, but the main

[1] A minor branch of the South Equatorial current of the Indian Ocean seems to be deflected by the Saya de Malha Bank eastwards, between the Chagos Archipelago and the Maldives, thus forming the *Equatorial counter-current* of this ocean. Similar retrograde currents occur also in the Atlantic and Pacific oceans, forming a surface drift flowing between the north and south Equatorial currents, but in an exactly opposite direction.

portion is deflected due east as the great *Southern Connecting current* of the Indian Ocean, which sets towards Australia with an initial velocity of 50 miles a day, and, aided by the prevalent westerly winds, enables vessels to make a quick passage from the Cape to Australia and New Zealand. This current flows in the same general direction as the Antarctic drift-current, of which it forms indeed the northern limits, and with which it is carried along to the east, one portion being deflected off Cape Leeuwin to the north, while the other portion continues its easterly flow south of Australia, and is finally deflected north along the west coast of New Zealand.

252. The *greatest depth* hitherto discovered in the Indian Ocean is in the deep basin bounded by Java, Flores, and Timor on the north, and the Australian coast on the south. Here the *Gazelle* took two soundings of 3,010 and 3,020 fathoms respectively. South of latitude 35° the general depth varies from 2,000 to 1,500 fathoms, while the main basin has an average depth of upwards of 2,500 fathoms, deepening towards the east to 3,000 fathoms. South of Australia the general depth is not far short of 2,000 fathoms ; which is also the depth of the Bay of Bengal, and the basin between Mauritius and Madagascar. The Mozambique Channel, Red Sea, and Persian Gulf are each under 1,000 fathoms in depth.

253. As regards the *form of its bed*, the various soundings taken in connection with submarine telegraphs, and the results of the *Gazelle* and *Challenger* expeditions, enable us to form a general but pretty accurate idea of the bottom of the Indian Ocean. The islands and archipelagos are of course but the summits of extensive submarine plateaux. A series of lines connecting the various islands, however, do not mark accurately the direction and limits of the elevated parts of the sea-bottom, and require to be supplemented by several series of soundings. Thus the Chagos Archipelago might at first sight be taken to indicate the existence of a continuous ridge or plateaux under water, from the Maldives to the Mauritius

and adjoining islands and banks; whereas the fact is that the Chagos are situate in the middle of the only deep-sea channel communicating between the Arabian Sea and the *main basin* of the Indian Ocean. The latter lies north and east of the Kerguelen plateau, extending from Marion and Prince Edward Islands to St. Paul and Amsterdam Islands; a line through Cape Agulhas, Madagascar, Rodrigue, Chagos Islands, to Cape Comorin, limits it on the west; the Bay of Bengal is its most northerly, and the Arafura Sea its most easterly, extension. This basin is also extended south of Australia and Tasmania, and probably opens into the southern basin of the Pacific by a depression south of New Zealand. The average depth of the main basin, in a line from South Africa to Java, is over 2,500 fathoms, deepening in the angle south-east of the latter to 3,000 fathoms. What may be called the *North-western Basin* of the Indian Ocean is separated from the main basin by the line of islands extending from the south-western coast of India, by the Maldives, Chagos, Seychelles, Madagascar, to Mozambique. The Red Sea and Persian Gulf on the north, and the Mozambique Channel on the south, of this basin, are all under 1,000 fathoms in depth. From the equator to 10° N. lat. the average depth is about 2,500 fathoms; further north it sinks rapidly to 1,000 fathoms and under. The narrow but deep depressions between the Maldives and Chagos, and the latter and the Saya de Malha Bank, connects this basin with the main basin on the east. A smaller basin, having an extreme depth of 2,000 fathoms, lies between the east coast of Madagascar and the line of islands and banks extending from Cape Amber, by the Amirante Islands, Seychelles, Saya de Malha Bank, Albatross, Mauritius, and Bourbon. This minor basin might be called the "Sea of Mascarhenas," from the discoverer of the principal islands limiting it on the east.

254. The *South-western Basin* of the Indian Ocean is entirely included in the so-called Southern Ocean, and extends

from the Antarctic plateau on the south to the Kerguelen plateau (of which Marion, Prince Edward, Crozet, Kerguelen, Amsterdam, and St. Paul's islands are the highest points) on the north. Both these plateaux have a general elevation of about 1,500 fathoms below the sea-level; the deeper portions of the intermediate depression between them have an average depth of about 2,000 fathoms.

The Indian Ocean.—Navigation and Commerce.

255. Before the introduction of steam as a motive power the navigation of the northern parts of the Indian Ocean was especially hazardous—the complicated and uncertain currents, the monsoons and hurricanes, the deficiency of sheltered ports and roadsteads, frequently combined to imperil the old "Indiamen," laden with the valuable products of India, China, and Malaysia. The construction of the Suez Canal has rendered the Red Sea a most important commercial highway, which is now regularly navigated by steamers, with mails and passengers, transports with troops and stores for India, and other vessels to and from the East Indies, China, and Japan. The route round the Cape of Good Hope to India (Calcutta) is much longer, being nearly 12,000 nautical miles, while the route by Gibraltar, Malta, Suez, and Aden is a little over 7,500 nautical miles. From Cape Town, on the south, four main lines of navigation radiate to India, along the African coast through Mozambique Channel, or east of Madagascar by way of the Mauritius; to Java, and other islands of Malaysia; and by the China Sea to China and Japan; and to Australia and New Zealand, due east,—the course being generally within the limits of the great counter-current of the Indian Ocean. Next to the Red Sea and Suez Canal, the Straits of Malacca and Sunda are the most important and frequented channels, communicating as they do with the Indian Ocean and the Bay of Bengal on one side, and the China Sea and the West Pacific on the other. The

Portuguese were the first of the great maritime nations of Europe to navigate the Indian Ocean, and were soon followed by the Spaniards, Dutch, French, and, lastly, the English. In course of time the latter, by the conquest of India, made themselves supreme in this ocean, and at present by far the greatest proportion of its commerce is in their hands. The Dutch have also important trade relations with their East Indian possessions. The following table shows the principal articles of export and import of the countries bordering on the shores of the Indian Ocean. The extent of the direct trade with the United Kingdom may be inferred by comparing the amounts in the two last columns with the value of the total exports and imports of each country.

**** *The values given are taken from the latest official returns.*

1	2	3	4	5	6	7	8
Country.	Imports.	Value.	Exports.	Value.	Principal Ports.	Value of Imports from Gt. Britain & Ireland.	Value of Exports to Gt. Britain & Ireland.
		£		£		£	£
C. Colony	*See Atlantic.*				Mossel B., Port Elizabeth, E. London.		
Natal.....	Manufactured goods, tea, wines and spirits, &c.	1,167,402	Wool, hides, ivory, sugar.	689,817	D'Urban.	226,781	682,015
Portuguese Possessions	Cotton goods, arms, beads, &c.	—	Ivory, rice, &c.	—	Mozambique, Sofala, Inhambane, Quillimane.	—	—
Zanguebar	Cotton goods, beads, brass wire, arms, &c.	429,053	Ivory, gum-copal, cloves, cocoa-nut oil, &c.	495,789	Zanzibar.	—	—
Arabia	Cotton, cloth, sugar, arms, ammunition, &c.	—	Wool, coffee, sheep, camels, horses, dates, and pearls.	—	Jeddah, Mocha, Aden, Muscat.	—	—
Persia	Cotton goods.	About 1,500,000	Raw silk, tobacco, opium, fruits, carpets, shawls.	About 1,000,000	Bushire.	152,198	173,358

TABLE OF COMMERCE.—*(Continued).*

1	2	3	4	5	6	7	8
		£		£		£	£
India	Cotton and woollen goods, coal, hardware and machinery, spirits, wines, &c.	—	Rice, tea, coffee, sugar, cotton, indigo, opium, silk, jute, hides, pepper, teak, &c.	—	Bombay, Madras, Calcutta.	—	—
Further India....	Tea, opium, cotton, woollen goods, &c.	—	Rice, cotton, ivory, sugar, pepper, various minerals, petroleum, teak, guttapercha, &c.	—	Bangkok, Rangoon.	—	—
Straits Settlements	Manufactured goods, &c.	—	Sugar, rice, sago, pepper, spices, dyes, tea, coffee, &c.	—	Singapore, Malacca.	1,882,785	2,536,958
Java	Cotton goods and yarn.	About 7,010,000	Sugar, coffee, tobacco, indigo, rice, &c.	About 10,200,000	Batavia, Samarang.	1,455,934	1,850,643
Sumatra, &c.	Do.	—	Do.	—	Achin, Padang, Bencoleen.	—	—
West Australia .	Sugar, tea, coffee, tobacco, and other colonial produce, manufactured goods.	379,049	Wool, lead and copper ore, guano, sandal-wood, pearls, &c.	428,491	Freemantle.	157,229	204,061

1	2	3	4	5	6	7	8
		£		£		£	£
South Australia..	Colonial produce and manufactured goods, coal, timber.	5,719,611	Wool, wheat and flour, copper.	5,355,021	Adelaide, Port Wakefield, Port Lincoln.	2,627,774	3,079,218
Victoria.....	Do.	16,161,880	Wool, gold, tallow, hides, preserved meat.	14,925,707	Melbourne, Geelong.	7,389,239	6,458,484
Tasmania	Do.	1,324,812	Wheat and flour, timber, wool, oil, tin.	1,315,695	Hobart Town, Georgetown.	293,263	501,115
Madagascar	—	—	—	—	Tamtave.	22,325	4,300
Mauritius	Rice, cotton goods, &c.	—	Sugar, rum, aloes.	—	Port Louis.	431,552	887,009
Ceylon	Manufactured goods.	—	Rice, coffee, cocoa-nut oil, cinnamon, pearls.	—	Galle, Colombo.	850,553	2,922,219

The Indian Ocean.—Historical Notes.

257. Unlike the Atlantic and Pacific Oceans, of which the nations of antiquity knew but little, the Indian Ocean seems to have been approached from South-eastern Europe overland by Persia and India, and by the Red Sea, at a very early period. If the *Ophir* of Scripture was the present Sofala, then Hiram's vessels must have passed down the Red Sea and the east coast of Africa, and through the Channel of Mozambique. Others assert that Ophir was the Malabar coast of India. Whichever view is the correct one, it is certain that the Phœnicians navigated the Indian Ocean even at that early period.

258. In the year 327, Alexander the Great invaded India through Afghanistan, and followed the Indus to its mouth whence one of his generals, Nearchus, sailed in the following year, with 30 galleys, to the Persian Gulf. We also know that, under the Ptolemies, Egyptian fleets frequently sailed from the Red Sea ports to India and the east coast of Africa. The Indian Ocean was also known to Herodotus, Ptolemy, and other ancient writers, as the *Erythræum Sea*—a name first given to the Red Sea, but subsequently extended to the Arabian Sea and Indian Ocean. Sulaiman, an Arab merchant and traveller in the ninth century, visited India and China *by sea*. Marco Polo, a Venetian, in 1265, with his father and uncle, travelled overland to China, and remained for 17 years in the service of the Emperor, Kublai Khan. On his return to Europe he wrote an account of his travels, which is by far the most important geographical production of the time, although disfigured with numerous improbable and incredible stories. Passing by the minor voyages and travels of several missionary monks to India and China about 1320, we come to the famous Arab traveller, Ibn Batuta, who commenced his travels in 1325. After a few land journeys in North Africa and South-western Asia, he sailed down the Red Sea to Aden, and

thence visited the East African ports of Mombas and Quiloa, whence he traversed the Indian Ocean to Ormuz, in the Persian Gulf. In 1342 he passed down the west coast of India, and after visiting Ceylon and the Maldives, proceeded to China through the Straits of Malaya.

259. But it was not until the establishment of a school of navigation at Sagres by Prince Henry of Portugal, that maritime discovery was fairly started. We have already, in our short notice of the Atlantic, followed the various voyages of discovery in that ocean to the year 1486, when Bartholomew Diaz first sighted the famous headland, which he named *Cabo Tormentoso*, or Cape of Tempests, afterwards changed by King John of Portugal to *Cabo de Bona Esperanza*, Cape of Good Hope. Eleven years later this long-sought Cape was doubled by Vasco de Gama, and the passage by sea to India opened to European enterprise and ambition. De Gama left Lisbon on the 8th of July, 1497, with four vessels, and doubled the Cape on the 22nd of November. On Christmas Day the coast of *Natal* was sighted, and in April he arrived at *Mombas*, whence he sailed to *Calicut*. On his return, the Portuguese king decided to found settlements along the south coast of Asia, and on the 9th March, 1500, Pedro Cabral left Lisbon with 13 vessels, but, bearing too much to the west on his way to the Cape, the vessels were driven towards the coast of Brazil. Naming the newly-discovered land *Terra da Santa Cruz*, the "Land of the Holy Cross," Cabral sailed from the port, now called Porto Seguro, to the Cape, and thence across the Indian Ocean to Calicut. Gama, Saldanha, and Almeida successively visited India, and in 1506, the great Albuquerque, being appointed Viceroy of the Indies, conquered Goa, which thenceforth formed the chief settlement of the Portuguese, whence they extended their conquests north to Ormuz, in the Persian Gulf, and east to the Malay Archipelago. The Spaniards being desirous of discovering a westerly route to the East Indies, Magellan was

sent out with five ships in 1519. After a most successful voyage by way of Magellan Straits, he reached the Philippines, where he was unfortunately killed by the natives. Only one of his vessels, the *Vittoria*, left the Moluccas, and, sailing across the Indian Ocean to the Cape, eventually reached Portugal (1522), being thus the first vessel to circumnavigate the globe.

260. Drake, in the course of his voyage round the world, crossed the Indian Ocean in 1580. Lancaster's voyage to India (1591-4) led to the formation in 1599 of the East India Company. The first fleet sent out was commanded by Sir James Lancaster, with John Davis as pilot-major, but did not proceed further than Achin. The first landing on the coast of India was made at Surat by Hawkins, in command of the Company's fleet. The English were soon followed by the Dutch, who formed an East India Company in 1602, and possessed themselves of Java and other islands of the Indian Ocean. From Java discoveries were gradually made to the south, and in 1601 Godinho seems to have sighted the north-western coast of Australia, then vaguely known as Great Java, which was again visited by the Dutch ship *Dove* in 1606. Ten years later Dirk Hartog sailed along the west coast of New Holland as far south as Shark Bay ; the largest of the three islands at the mouth of which is still called after him, Dirk Hartog's Island. In 1622 the Dutch vessel *Leeuwin* approached the south-western extremity of Australia (Cape Leeuwin) and five years later another Dutch vessel doubled this point, and skirted the western portion of the Great Australian Bight. Abel Tasman left Batavia in August, 1642, and on November 24th, Van Diemen's Land was first seen. Thence Tasman proceeded eastward to Staten Land (New Zealand). Cook, on his voyage home in 1770, passed from the Pacific into the Indian Ocean through Torres Straits, and having touched at Batavia, sailed thence to the Cape and England. Kerguelen, in 1771, discovered the island which

bears his name, but which at first was more appropriately called the Island of Desolation. In 1797 Mr. Bass explored the strait between Victoria and Tasmania; and in 1801 Captain Flinders was sent out, and surveyed the Australian coasts from King George's Sound, by Bass Strait, to the Gulf of Carpentaria. Two French vessels—the *Geographe* and *Naturaliste*—also explored the West Australian coasts at the same time. Now the work of discovery in the Indian Ocean was complete, and its shores, islands, reefs, and shoals have since been accurately mapped out for the guidance of the vast fleets that constantly cross and recross it. The operations in connection with submarine telegraphy in the north, and the *Challenger* expedition in the south, have furnished data which enables the geographer to supplement his knowledge of the horizontal configuration of this ocean by pretty accurate ideas of the conformation of its bed and the temperature and movements of its waters.

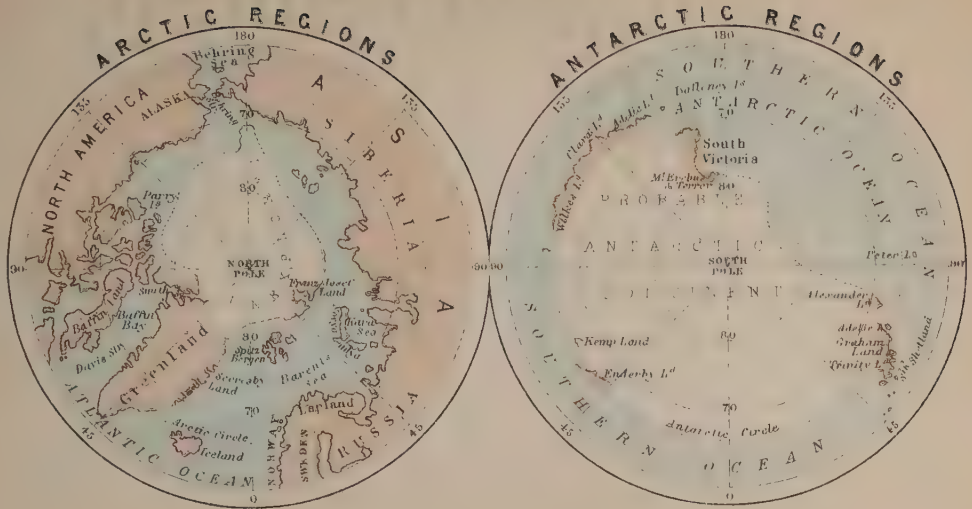
IV.

THE ANTARCTIC OCEAN

The Antarctic Ocean.—Generalities.

261. The Antarctic Ocean is the name given to the whole body of water comprised within the Antarctic Circle, but which is of limited extent, if it be true that the various portions of land sighted on or near the circle are the coasts of an immense circumpolar continent. The Antarctic Circle is for the most part merely a theoretical or imaginary boundary, there being no continuous *natural* limit to the South Polar basin, which opens broadly into the Pacific, Atlantic, and Indian Oceans. The portions of these oceans extending south of Cape Horn, Cape of Good Hope, and Tasmania, to the Antarctic Circle, belong therefore, *naturally*, to a continuous depression extending right round the globe, and gradually shoaling towards the South Pole. The whole of this expanse, as well as the water area actually within the Antarctic Circle, forms, in fact, but *one* ocean—the great "Southern Ocean"—which is, physically, the most important of all the divisions of the great "world of waters." It is in this vast basin that those grand movements of tides and currents originate—here they receive their primary impulse, and hence they are propagated into the other great oceans.

262. As the Atlantic, Pacific, and Indian Oceans communicate freely towards the south, there was no necessity—as in the case of the Arctic Ocean, where the passage both east



George Philip & Son, London & Liverpool

and west is blocked by land and ice—for any investigation of the Antarctic Ocean from a purely commercial point of view, and it thus offered but few inducements which stimulated repeated researches in the Arctic Seas; and moreover, the violent tempests which sweep over this inhospitable waste of waters, together with the vast number of icebergs which constantly encumber it, render its navigation most difficult and dangerous. A few daring navigators have indeed gallantly crossed the Antarctic Circle, but with the exception of Sir James Ross and Weddell, none of them reached the 72nd parallel: all being stopped by icefields or icebanks, skirting inaccessible coasts, lying generally on or near the Antarctic Circle. The principal known points are *Graham Land*, *Trinity Land*, with the adjoining islands, Alexander, Adelaide, South Shetlands, South Orkneys, &c., south of Tierra del Fuego; *Enderby* and *Kemp Land*, south of the Crozet Islands: the irregular coasts of *Sabrina Land*, *Clarie Land*, and *Adelie Land*, south of Australia; and the great bend off the *Balleny Islands*, penetrated by Sir James Ross as far as lat. 78° 15′ S., where he found "an unbroken vertical cliff of ice, of about 1,000 feet in thickness, and floating in 280 fathoms of water, extending eastward for 450 miles." The principal landmarks on the dreary and most inhospitable coast of *Victoria Land* are a range of mountains running south, culminating in Mts. Sabine, Crozier, Erebus, an active volcano 12,367 feet high, and Terror, an extinct volcano, 10,889 feet above the sea level.

263. The portions of land discovered within the Antarctic Circle is almost everywhere inaccessible, and, where surrounded by open water, landing is rendered impossible by enormous icebanks, of from 5 to 20 miles wide, which skirt the coasts. The mountains of Adelie Land are probably of an average height of 1,000 feet, with almost vertical slopes; the intervening valleys being filled with ice and snow, pressed by continual accumulations into vast glaciers. The con-

stantly increasing pressure forces the glaciers forward, so that their lower ends project far out in the water. By the action of the waves, tides, and storms, vast pieces are continually being broken off, and thus are formed the *icebergs* of the Southern Ocean, immense numbers of which are found even in summer as far north as 55° or 50°—that is, 10° nearer the equator than those of the Arctic Ocean. The Antarctic icebergs are not, like those of the North Polar Sea, irregular and fantastic in shape, but are mostly flat-topped, rising perpendicularly out of the water. The vast belt of water between 50° and 70° S. lat. being constantly covered with ice, either in immense "fields" or detached "floes" or "bergs," is consequently kept at a low temperature; hence the coldness of the vast north-easterly drift known as the *Antarctic drift current.*[1]

264. In the wide inlet discovered by Ross, the depth nowhere exceeded 500 fathoms, and it is probable that the average depth of the deepest parts within the Antarctic Circle is under 1,500 fathoms. The maximum depth found within the Antarctic Circle by the *Challenger* expedition, south of Termination Island, was 1,975 fathoms, or 11,850 feet.

265. The whole of the Antarctic regions are within the *snow-line*, and no vegetation is known to exist south of Cockburn Island (64° 12′ S. lat., 54° 49′ W. long.), and even there it disappears entirely at an elevation of 1,000 feet. In reference to the *animal life* of the South Polar regions, Sir John Richardson says that "no terrestrial quadruped inhabits the lands within the Antarctic Circle; the marine cetaceans and seals being the only mammals that enter its area, or approach it within many degrees of latitude. Organised specially to inhabit the chilly Antarctic waste of waters, the

[1] One portion of this drift is deflected north off Cape Horn, and flows towards the equator, along the western coasts of South America, as the *Peruvian* or *Humboldt's Current*, the low temperature of which betrays its origin

almost scaly *penguins* resemble the walrus and seals, in being able to travel long and far beneath the surface of the ocean in seeking their food in its depths, and scarcely quitting it except for the purpose of incubation. Indeed, one species—the *solitary penguin*—carries its eggs with it in a fold of skin when it roams far in search of food. The existence of such a creature, and of the *dodo*, *moa*, &c., furnishes an argument of certain species having been created solely for limited districts."

The Antarctic Ocean.—Historical Notes.

266. The discovery of the continent of America by Columbus revived in full force the theoretical notion of the old geographers relative to the existence of a vast continent to the south. The search for this *Terra Australis Incognita*—as the probable southern continent was called—engrossed the attention of the maritime nations of Europe for more than 200 years.

267. In Jan. 1600, a Dutch squadron, bound for the East Indies, passed through the Strait of Magellan into the Pacific. One vessel, however, commanded by Dirk Cherrits, failed to enter the straits, and was driven south, and in lat. 64° discovered a snow-covered coast, afterwards named New South Shetland. Captain Kerguelen, in 1769-70, explored the area between Desolation or Kerguelen Island and Australia. The existence of a great continent was, however, still entertained, and on the 13th of July, 1772, the famous Captain Cook sailed from Plymouth in command of H.M.S. *Resolution*, accompanied by H.M.S. *Adventure*, Captain Furneaux. The object of the expedition is thus stated by the great navigator:—"Whether the unexplored part of the Southern Hemisphere be only an immense mass of water, or contain another continent, as speculative geography seemed to suggest, was a question which had long engaged the attention, not only of learned men, but of most of the maritime powers of Europe. To put an end to all diversity of opinion about a matter so curious and important, was his Majesty's principal motive in directing this voyage to be undertaken."

268. On the 22nd November, the same year, the expedition left the Cape of Good Hope for the south, and on the 14th of December they first sighted the ice. The Antarctic Circle was crossed on the 17th Jan. in long. 39° 35′ E., but the gradual accumulation of ice-fields and bergs obliged Cook to retrace his way north again. On the evening of the 8th February the *Adventure* was lost sight of in a fog, and proceeded to Queen Charlotte Sound, in New Zealand, where she was joined by the *Resolution*. The following summer the vessels again parted company on their way south. The *Resolution* crossed the Antarctic Circle and pushed south, the highest point reached (30th Jan. 1774) being in 71° 10′ S. lat., and 106° 54′ W. long., where she was stopped by an immense ice-field, and obliged to return north. Cook says that this ice-field "extended east and west, far beyond the reach of sight. . . . Ninety-seven ice-hills were distinctly seen within the field, besides those on the outside; many of them very large, and looking like a ridge of mountains, rising one above another till they were lost in the clouds. The outer or northern edge of this immense field was composed of loose or broken ice, close packed together, so that it was not possible for anything to enter it. This was about a mile broad, within which was solid ice in one continued compact body. It was rather low and flat (except the hills), but seemed to increase in height as you traced it to the south, in which direction it extended beyond our sight. I will not say it was impossible anywhere to get further to the south, but the attempting it would have been a dangerous and rash enterprise." In his third expedition to the south, Cook discovered *South Georgia*, and the Sandwich group called by him *Southern Thule*. Cook thus sums up the results of his observations:—"I had now made the circuit of the Southern Ocean in a high latitude, and traversed it in such a manner as to leave not the least room for the possibility of there being a continent, *unless near the pole*"; and he considers that "a final end has been put to the searching

after a southern continent, which has at times engrossed the attention of the maritime powers for two centuries past, and has been a favourite theory amongst the geographers of all ages"; but still he firmly believed that "there is a tract of land near the pole, which is the source of most of the ice that is spread over this vast Southern Ocean."

269. The idea of a vast continent between the 50th and 70th parallels was thus dispelled, and Antarctic exploration was consequently neglected. The South Shetlands, first seen by Cherrits in 1599, were accidentaly re-discovered by Mr. Smith, of the brig *William*, bound for Valparaiso. Smith reported the discovery to H.B.M.'s Consul at Valparaiso, who sent the *Andromache*, Capt. Barnsfield, to explore the islands. In 1821 several discoveries were made to the south and west of the South Shetlands—Trinity Land, first seen by Powell; Palmer's Land by an American, Palmer; Petra and Alexander Islands by the Russian, Bellinghausen. In 1822 Weddell set out with two vessels, the *Jane*, of 160 tons, and the *Beaufoy*, of 65 tons, to procure seal skins in the South Seas. Ice was first met with in lat. 59° 37′, near the South Orkneys. The highest latitude was reached in January 1823, in lat. 74° 15′, long. 35° W., nearly three degrees further south than Cook.

270. In 1830 Biscoe set out for the South Seas in command of the brig *Tula* and the cutter *Lively*, belonging to Messrs. Enderby. Leaving the Falkland Islands on the 8th November, they discovered land on the 27th January in the following year, in lat. 65° 57′ S., and long. 47° 20′ E. Here the explorers first saw the *Aurora Australis*, described by Biscoe as "at times, rolling, as it were, over our heads in the form of beautiful columns, then as suddenly changing like the fringe of a curtain, and again shooting across the hemisphere like a serpent; frequently appearing not many yards above our heads, and decidedly within our atmosphere. It was by much the most magnificent phenomena of the kind that I

ever witnessed; and although the vessel was in considerable danger, running with a smart breeze, and much beset, the people could scarcely be kept from looking at the heaven instead of attending to the course." Naming the newly discovered land Enderby Land, the *Tula* proceeded north to Van Diemen's Land, but returned again in January 1832, and in the following month Adelaide Island, and the adjoining islands and mainland called Graham Land, were discovered.

271. In 1839 Balleny discovered the group of islands named after him, and also sighted Sabrina Land, which, however, was inaccessible. In 1837 Dumont D'Urville was sent in command of the *Astrolabe* and *Zélée*, fitted out by the French Government for the exploration of the Antarctic Seas. On the 18th of January the following year they touched the ice in lat. 50° 30′ S., and thence to the South Orkneys the sea was covered with floating ice, which rendered further progress south impossible. D'Urville thereupon sailed towards the South Shetlands, and explored a new coast-line for 120 miles between 63° and 64° S., to which he gave the name of Louis-Philippe's Land. In January 1840 D'Urville returned south, and crossed the Antarctic Circle on the 20th of the same month. Shortly after land was seen, towards which the vessels threaded their way through "lanes of ice." The newly-discovered land was named Adelie Land, after the commander's wife. A violent storm drove both the vessels off the land, which D'Urville intended to explore thoroughly, and on approaching it again on the 29th, one of the vessels belonging to the American Antarctic Expedition was sighted, but not communicated with. The next day the ice-barrier that skirts the coasts of Clarie Land was followed for some miles, but no opening being found, further search was abandoned, and the expedition returned home.

272. In the same year (1837) the American Government had also fitted out an expedition, consisting of five vessels, under

the command of Lieutenant Wilkes, for the exploration of the South Polar Seas. Leaving Sydney on the 26th Dec., the vessels worked their way south, and on the 23rd Jan. a large open bay (Disappointment Bay) was entered, which, however, proved to be so surrounded on all sides by ice, that the land—which undoubtedly lay both to the east and west—could not be approached. The great danger to which vessels are exposed in the Antarctic Seas will be seen from the following extract from the pen of the commander, Wilkes:—"We were swiftly dashing on, for I felt it necessary to keep the ship under rapid way through the water, to enable her to steer and work quickly. Suddenly many voices cried out, 'Ice ahead!'—then, 'On the weather-bow!'—and again, 'On the lee-bow and abeam!' All hope of escape seemed in a moment to vanish. Return we could not, as large islands had just passed to leeward; so we dashed on, expecting every moment the crash. The ship in an instant, from having her lee-guns under water, rose upright, and so close were we passing to leeward of one of these huge islands, that our trysails were thrown aback by the eddy-wind. The helm was put up to pay the ship off, but the proximity of those under my lee bade me keep my course. All was now still, except the distant roar of the wild storm that was raging behind, before, and above us; the sea was in great agitation; and both officers and men were in the highest degree excited. The ship continued her way, and as we proceeded a glimmering of hope arose, for we had accidentally hit upon a clear passage between two large ice-islands, which in fine weather we should not have dared to venture through. The suspense endured while making our way between them was intense, but of short duration; and my spirits rose as I heard the whistling of the gale grow louder and louder before us as we emerged from the passage. We had escaped an awful death, and were again tempest-tossed." Notwithstanding the dangers and difficulties encountered, Wilkes persevered in his search, and on the 30th

of January land was apparently sighted, extending east and west, rising above the ice-banks which enclosed it to a height of 3,000 feet. The vessels skirted the ice-banks of the supposed land for several days, which everywhere presented the same precipitous, unbroken appearance, and nowhere accessible. The only "landing" effected was on an iceberg, the surface of which was strewn with stones and other débris. Nothing further was done, and the expedition returned north.

273. In 1839 Sir James Clark Ross was sent out in command of an expedition fitted out by the British Government to determine the position of the South Magnetic Pole, and to explore the Antarctic Seas in the highest possible latitude. On the 12th of May, 1840, the *Erebus* and *Terror* arrived at Kerguelen Island, and returned the following month to Hobart Town, where Ross was informed of the discoveries of the American and French Expeditions in the very localities which the English Expedition had been expressly ordered to examine. He therefore "resolved at once to avoid all interference with their discoveries, and selected a much more easterly meridian (170° E.), on which to endeavour to penetrate to the southward, and, if possible, reach the Magnetic Pole." Leaving Hobart Town on 13th November, Ross again sailed south, reaching Enderby Island on the 28th, and exactly a month later the vessels were amongst the icebergs. The Antarctic Circle was shortly after crossed, and the ships were steered for the *South Magnetic Pole*. On the 11th of January, 1841, the distant heights of Victoria Land were seen. Doubling Cape Adare, the vessels approached the land. "It was a beautiful, clear evening, and we had a most enchanting view of the two magnificent ranges of mountains, whose lofty peaks, perfectly covered with eternal snow, rose to elevations varying from seven to ten thousand feet above the level of the ocean. The glaciers that filled their intervening valleys, and which descended from near the mountain summits, projected in many places several miles into the sea, and terminated in

lofty perpendicular cliffs. In a few places the rocks broke through their icy covering, by which alone we could be assured that land formed the nucleus of this, to appearance, enormous iceberg." It was found impossible to land on the mainland, and only with great difficulty could a landing be effected on an island (Possession Island) composed entirely of volcanic rocks, utterly destitute of vegetation, but the abode of "inconceivable myriads of penguins." Steering south along the coast, the magnificent ranges sighted on the 11th were fully in view on the 15th. The highest points were estimated to be from 10,000 to 14,000 feet in height, and were entirely covered with snow. Naming the highest peak after Sir John Herschel, the vessels stood south, and on the 21st the immense crater of Mt. Melbourne, and the pointed summit of Mt. Monteagle, were sighted. On the 27th landing was effected on an island in lat. 75° 48′ S., and named Franklin Island, and pressing still south, a magnificent active volcano, Mt. Erebus, 12,360 feet high, was sighted and approached on the 28th.[1]

274. The ice-barrier was skirted for about three weeks in the hope of discovering an opening through which the vessels might push further south, but it was found to be impenetrable. Ross therefore returned, and retraced the coast of

[1] Mt. Erebus was "observed to emit smoke and flame in unusual quantities, producing a most grand spectacle; a volume of dense smoke was projected at each successive jet with great force, in a vertical column, to the height of between 1,500 to 2,000 feet above the mouth of the crater, when, condensing first at its upper part, it descended in mist or snow, and gradually dispersed, to be succeeded by another splendid exhibition of the same kind in about half an hour afterwards, although the interval between the eruptions were by no means regular. The diameter of the columns of smoke was between two or three hundred feet, as near as we could measure it; whenever the smoke cleared away, the bright red flame that filled the mouth of the crater was clearly perceptible, and some of the officers believed they could see streams of lava pouring down its sides until lost beneath the snow, which descended from a few hundred feet below the crater, and projected its perpendicular icy cliff several miles into the ocean. Mount Terror was much more free from snow, especially on its eastern side, where were numerous little conical crater-like hillocks, each of which had probably been at some period an active volcano."

Victoria Land, the highest point attained being 78° 4′ S. Being unable to find an anchorage where the expedition might winter safely, Ross decided to return north, and, if possible, examine closely the shores of the "Antarctic Continent" of Wilkes. On the 5th March the vessels approached the land marked on Wilkes's chart, but failed to discover any sign of it, although the weather was beautifully clear; and on the 6th the vessels actually passed over the supposed coast-line. After thus proving Wilkes Land to be hypothetical, the vessels proceeded to Van Diemen's Land.

275. In the following year Sir James again sailed south, and examined the ice-barrier, but failed to find an opening, and returned to the Falkland Islands on the 6th of April. In December 1842 the *Erebus* and *Terror* stood south for the third time, but in a different direction, the object being to trace the coast-line of Louis Philippe's Land, or follow the track of Weddell. During this voyage several small islands and islets (Ætna, Danger, Darwin, &c.) were discovered. The mainland was sighted on the 30th of December, and on New Year's Day, 1843, landing was effected on Cockburn Island, remarkable as being the furthest southerly land on which vegetation is found. It being impossible to penetrate the heavy pack-ice met with at all points, the expedition returned, arriving in England in September 1843. Of these remarkable voyages Sir John Richardson well remarks, that "the perseverance, daring, and coolness of the commanding officer, of the other officers, and of the crews of the *Erebus* and *Terror*, were never surpassed, and have been rarely, if ever, equalled by seamen of any nation."

[The *Challenger* crossed the Antarctic Circle in long. 78° E., on the 16th of February, 1874, and proceeded through the pack-ice and bergs to lat. 66° 40′ S., but as no land was seen in any direction, the Circle was re-crossed the same day.]

V.

THE ARCTIC OCEAN.

The Arctic Ocean—Generalities.

276. The Arctic Ocean comprises the whole water-area within the Arctic Circle, and is almost completely enclosed by the northern coasts of the Old and New Worlds. With the exception of a southerly bight opening into Behring's Strait, the coasts of Asia, from the mouth of the Kolyma eastwards, and those of North America and Northern Europe, generally conform to the parallel of 70° N. lat.; but the Siberian coast, from the Gulf of Obi to the mouth of the Kolyma, has a more northerly trend, reaching in Cape Chelyuiskin, the extreme northern point of the Old World, the high latitude of 78° 12′ N., thence gradually receding to latitude 70° N. at the mouth of the Kolyma. The North Polar Seas thus touch the Arctic Circle only at the northern end of Behring's Strait, Davis Strait, Denmark Strait, and the wide expanse between Iceland and Norway. These channels form the only water communication between the Arctic and the Pacific and Atlantic Oceans —Behring's Strait leading into the former, and Davis Strait and the wide channel between Greenland and Norway into the latter.

277. The Arctic Ocean is thus nearly circular in form, being comprised within a radius of twenty degrees from the central point, the North Pole. It is also almost landlocked; of its entire circumference, only about 1,500 miles are open—about

50 into the Pacific, and the rest into the Atlantic. The diameter of the space thus limited is about 2,500 miles, and the total area 5,550,000 square miles. The icebound condition of the Arctic Sea has utterly defeated all attempts hitherto made to penetrate northwards to the Pole. As we shall again observe, the *Alert* wintered in the northern extremity of Robeson Channel, and Commander Markham succeeded in pushing as far as 83° 20′ 26″ N. latitude; but, generally speaking, the whole of the North Polar regions circumscribed by the 80th parallel is unknown—the belt between the 80th and the 70th parallels is but partially known—while the portions south of the 70th parallel may be said to be well known.

278. The Arctic Ocean encroaches on Europe in the White Sea—on Asia in the Gulfs of Kara, Obi, and Yenesei; between Asia and Alaska is the strait of Behring, the only channel of communication with the Pacific. The northern shores of North America are extremely indented and skirted by a most irregular assemblage of islands, thus forming numerous gulfs, straits, and channels, the principal of which are Baffin Bay and its northerly prolongations, Smith Sound, Kennedy and Robeson Channels; Lancaster Sound, Barrow Strait, Melville Sound, and Banks Strait; Coronation Gulf, Dease Strait, Simpson Strait, Gulf of Boothia, Fury and Hecla Strait, Fox Channel and Hudson Strait, and many other minor channels which need not be enumerated here.

279. Of the land-masses belonging to this ocean the principal are:—Greenland, now known to be an island, extending on the west to lat. 82° 54′ N.; Spitzbergen, Franz Joseph Land, Nova Zembla, between the Pole and Northern Europe; Liakhov Islands or New Siberia, Kellet Land, off the coast of Siberia; and the extensive archipelago north of North America, comprising Baffin Land, Victoria, Prince Albert and Banks Land, Prince of Wales Land, North Somerset and North Devon, Parry Islands (Prince Patrick, Melville, Cornwallis, &c.), and the large mass north of Jones Sound, the eastern and north-

eastern shores of which only have been explored, but which seems to terminate northwards in Cape Columbia, and is thus probably the extreme northerly prolongation of the Arctic Archipelago. The last English expedition definitely determined the northerly limit of *land* in this direction, but instead of a perfectly open sea beyond, ice of immense thickness barred further progress towards the Pole.

280. The Arctic Ocean receives the drainage of an immense extent of land, comprising the whole of the Asiatic continent north of the Aldan and the Altai Mountains, and Kirghis Steppe; Russia, north of latitude 60°; North America west of a low watershed running from Boothia south-west to Lake Athabasca and the Rocky Mountains. The *Asiatic section* of the Arctic river-system embraces the Kolyma, Indigirka, Lena, Olenek, Yenesei, and Obi, of which the two last and the Lena are the largest. The Siberian plain, which they traverse longitudinally, is over 1,000 miles wide, and the slight fall of the land renders them extremely sluggish except when in flood. Being frozen during the greater part of the year, and flowing through a thinly populated, marshy, and inhospitable country, their commercial importance is inconsiderable. The recent explorations of Dr. Nordenskiold, and his splendid discovery of the long sought North-east Passage, may probably lead to the establishment of some trade between the Western European nations and Asiatic Russia, but it can never be very extensive or important, as both the rivers and their outlets, as well as the ocean into which they enter, are frozen over, and consequently unnavigable, during the greater part of the year.

281. The *European section* is limited—the rivers being few in number, and of no great importance. The principal are the Onega, Dwina, and Mezen, which enter the White Sea, and the Petchora, which falls into the Arctic Ocean.

282. The *American section* comprises one large river, the Mackenzie, and several smaller ones, such as the Colville,

Coppermine, and Great Fish River. The Mackenzie proper flows north from the Great Slave Lake, and, like the Colville, falls directly into the Arctic Sea. The Coppermine flows into Coronation Gulf, and the Great Fish River into the channel between Boothia and King William's Land. All these rivers discharge the collected drainage of a vast number of fresh-water lakes and swamps, connected together by numerous canal-like streams, such as the Slave River and others.

283. The Arctic River-System.

Section.	River.	Draining.	Length Miles.	Area of Basin. Sq. miles.
Asiatic.	Obi	Siberia	2600	1,250,000
	Yenesei	"	2900	1,100,000
	Lena	"	2500	960,000
	Indigirka	"	910	86,000
	Kolyma	"	800	107,000
European.	Petchora	North Russia	900	100,000
	Mezen	"	480	47,000
	Dwina	"	760	144,000
	Onega	"	380	22,000
American.	Mackenzie	N.W. of Brit. North America	2160	600,000
	Coppermine		450	—
	Great Fish		700	—

284. The best known currents of the Arctic Ocean are those that flow south on either side of Greenland, and, being deflected to the west, unite off Cape Farewell, and proceed south along the coast of Labrador as the great *Arctic Current*. Off the Grand Banks of Newfoundland this cold drift from the north meets the warm current of the Gulf Stream from the south; thence to Cape Hatteras we have

the remarkable phenomenon of two contiguous currents, one cold and the other warm, flowing in exactly opposite directions—the former south-west, the latter north-east. The cold current finally sinks under the Gulf Stream, and enters the Gulf of Mexico as an under-current. "The Arctic Current thus replaces the warm water sent through the Gulf Stream, and modifies the climate of Central America and the Gulf of Mexico, which, but for this beautiful and benign system of aqueous circulation, would be one of the hottest and most pestilential in the world." The north-easterly prolongation of "the Gulf Stream"—as the northerly set of the North Atlantic beyond the British Isles and Norway is sometimes called—seems to carry comparatively warm water right into the Arctic basin, due north between East Greenland and Spitzbergen, and eastwards between Nova Zembla and Franz Joseph Land. A branch of the latter is probably continued eastwards along the Siberian coast, and reinforced, more especially in summer, by the vast quantities of comparatively warm water discharged by the then swollen rivers of Siberia, moves towards Behring's Strait, where it is deflected to the north-east by the strong, warm current which sets into the Arctic from the Pacific through that strait. The united stream then flows north-east towards Parry Islands, and may probably be continued, through Melville Sound and Barrow Strait, into Baffin Bay—thus merging into the great Arctic Current, which pours south through Davis Strait. The probability of an open sea in the immediate neighbourhood of the Pole necessarily depends on the existence of a powerful warm under-current rising there to the surface. A continuous series of observations on the currents, &c., at accessible points within the partially known belt (70° to 80° N. lat.), would undoubtedly ultimately conduce to a far more successful research further north, than any spasmodic attempt to force a passage to the Pole without sufficiently numerous and recent data on which the best method of procedure could be based.

285. As regards its *depth*, the Arctic Ocean is, with one exception, nowhere much deeper than 1000 fathoms. The long slopes of Northern Asia and America indicate a continuous belt of shallow water, which the numerous islands further north prove to be continued in parts as far as 80° and 83° north latitude. The deepest known portion is the basin lying between the Arctic Circle and the parallel of 80° N., and from Spitzbergen and Norway on the east, to Greenland on the west. The Norwegian Expedition, on board the *Voringen*, obtained in August, 1876, a sounding of 1,800 fathoms between Iceland and Norway, and the whole basin has an average depth of over 1,000 fathoms. From the centre of this basin the precipitous cliffs of the volcanic island of Jan Mayen rise nearly 7,000 feet above the level of the sea. The depth near the ice-barrier which checked the progress of Sir George Nares was only 72 fathoms.

286. Among the remarkable features of the Arctic regions are the perpetual daylight in summer and constant darkness in winter, due to the inclination of the earth's axis to the plane of its orbit. The long winter night is occasionally relieved by the magnificent phenomenon, the *Aurora Borealis*, which is thus graphically described by Mrs. Somerville:—

"The Aurora is decidedly an electrical (or, more strictly speaking, a magneto-electrical) phenomenon. It generally appears soon after sunset in the form of a luminous arc, stretching more or less from east to west, the most elevated point being always in the magnetic meridian of the place of the observer; across the arc the coruscations are rapid, vivid, and of various colours, darting like lightning to the zenith, and at the same time flitting laterally with incessant velocity. The brightness of the rays varies in an instant; they sometimes surpass the splendour of stars of the first magnitude, and often exhibit colours of admirable transparency,—blood-red at the base, emerald green in the middle, and clear yellow towards their extremity. Sometimes one and sometimes a quick succession of luminous currents run from one end of the arc or bow to the other, so that the rays rapidly increase in brightness: but it is impossible

to say whether the coruscations themselves are actually affected by a horizontal motion of translation, or whether the more vivid light is conveyed from ray to ray. The rays occasionally dart far past the zenith, vanish, suddenly re-appear, and, being joined by others from the arc, form a magnificent corona or immense dome of light. The segment of the sky below the arc is quite black, as if formed by dense clouds; yet M. Struve is said to have seen stars in it, and so it would appear that the blackness of which several observers speak must be the effect of contrast. The lower edge of the arc is evenly defined; its upper margin is fringed by the coruscations, their convergence towards the north, and that of the arc itself, being probably an effect of perspective."

287. The almost constant precipitation of snow covers the whole of the Arctic highlands to an enormous depth, and the partial liquefaction in the short summer, and the accumulation in the long valleys and along the steep slopes of Greenland, &c., results in the formation of vast *glaciers*,[1] the lower end of which is gradually pushed out into the sea. Violent storms and other causes result in the breaking off of the projecting portions, which are thus free to move off with the winds or currents. These floating bodies of ice are the *icebergs*, so dangerous to navigation not only in the Arctic Seas, but also in the North Atlantic as far south as the 40th parallel. On the breaking up of the continuous winter-ice, immense numbers of these icebergs, or ice-mountains, are carried south by the Arctic current. Some are 250 to 300 feet high above the sea level, and as there must be about eight times as much below the surface of the water, the total height of a berg 300 feet above the surface is about 2,400 feet, hence they are often seen stranded a long distance from the shore.[2] Masses of ice, from a mile to fully 100 miles

[1] The most remarkable glacier is the *Great Humboldt Glacier*, in Greenland, about 90 miles north-east of Rensslaer Bay, between 79° and 80° north latitude, and 64° and 65° west longitude.

[2] The size of the portion under water varies, of course, with the *shape* of the berg.

across, and from ten to fifty feet thick, are frequently met with in motion. Portions detached from an *icefield*, as these continuous masses are called, form the floes or *floe-bergs*, and the irregular elevations on an icefield due to lateral pressure form the greatest obstacles to Arctic exploration, and are known as *hummocks*. The annual disruption of the great ice-fields formed during the intensely cold winter, results in the breaking off of innumerable masses of floe-ice, and in the separation of the larger 'fields.' Through the openings thus formed vessels push way to the open water beyond. Sometimes, however, the masses on either side close together, in which case the unfortunate vessel is thrown up on the ice, or held fast and drifted along with the ice-pack, and not unfrequently crushed and sunk.

[*Animal life* in the Arctic regions is abundant up to a very high latitude, musk-oxen, hares, and ptarmigans being found even as far north as 82°. The reindeer, musk-ox, Arctic fox, Arctic hare, wolf, and bear are also found, besides an enormous number of birds, including the guillemot, auk, puffin, merganser, goosander, smew, gull, eider-duck, wild swan, ptarmigan, &c. The seas are frequented by vast numbers of cod, capelin, halibut, dolphin, &c., and the right whale, rorqual, narwhal, various kinds of seals, and the walrus. During the summer months numbers of whaling vessels frequent the Polar Seas. Vast numbers of seals, &c., are also caught, and a large trade is carried on at the Danish settlements with the Esquimaux; furs (bear, fox, seal, &c.) being exchanged for European goods.]

The Arctic Ocean.—Historical Notes.

238. Passing over the semi-mythical voyages to Iceland, Greenland, and "many other islands beyond Norway, even under the North Pole," mentioned by Geoffrey of Monmouth and Lombard as having been made during the reign of the old British King Arthur—the exploits of the Heligolander Othar, of whom we are told, on the authority of Alfred the Great, that he "rounded the point of the globe beyond which

it sinks again to the south"—and the equally improbable voyage of Nicholas da Cynha in 1360 to the North Pole (?), but who probably never ventured further than the Hebrides or Faroe Islands—we come to the first properly authenticated account of an expedition of discovery in the Northern Seas. It is said that, upon the representation of Dr. Robert Thorne, of Bristol, Henry VIII. "sent two fair ships, well-manned and victualled, having in them divers cunning men, to seek strange regions" to the north of the British Isles. The expedition sailed from the Thames on the 20th of May, 1527, but all we know is that only one of the vessels returned, the other having been wrecked probably off the coast of Newfoundland. Hakluyt justly blames the writers of those times for not having kept a record of the "worthie acts" of the first actual expedition for the exploration of the Northern Seas sent out from this country. Nine years later, two small vessels, the *Trinitie* and the *Minion*, left Gravesend under the command of a Londoner named Hoare, but instead of pushing north, they sailed west to Newfoundland, where they suffered intensely from the cold and want of food. The survivors of this ill-fated expedition seized on a French vessel which fortunately arrived off the coast, and returned in her to England, followed some time after by the French mariners whom they had so unceremoniously treated. The latter laid their case before Henry VIII., and were fully recompensed for the seizure of their vessel by the English adventurers.

289. The Muscovy Company having obtained the exclusive right of trading to the northern regions, despatched, in 1553, three vessels under Sir Hugh Willoughby, with Richard Chancellor second in command, in the hope of discovering a passage to the "far Cathay," either right across the Polar Seas, or round the northern shores of Eurasia—the recently discovered route round the Cape of Good Hope being long and tedious, besides being controlled by the Spaniards and

Portuguese. Sir Hugh's vessel and another smaller one entered the river Arzina in Lapland, but during the winter all on board perished. Chancellor, in the other vessel, was more fortunate, and, after wintering in a Muscovite port, returned to England. The veteran explorer, Cabot, being nominated Governor of the Muscovite Company, pushed on the exploration of the Northern Seas—the advantages of an independent and shorter trade-route to the East being evidently of supreme importance to the Company. The *Search-Thrift* was therefore fitted out in 1556, under the command of the intrepid Burrough. Sailing north-east, he discovered the strait between Vaygatz Island and Nova Zembla; but was deterred from venturing into the Kara Sea by northerly winds and the "great and terrible abundance of ice." Entering the White Sea, he wintered at Archangel, returning to England the following year.

290. Queen Elizabeth, keenly conscious of the importance of the commercial interests of her country, stimulated the Muscovy Company to further efforts by threatening to revoke their charter, unless the passage that was to open up the wealth of Cathay to England was speedily discovered. This led to the despatch of three small vessels in 1576, under the famous Martin Frobisher, who sailed north as far as the mouth of the inlet now known as Frobisher Bay, and then returned. The following year a larger expedition, under the same leader, left Gravesend in May, and returned in December with a large quantity of ore, supposed to contain gold. The maiden Queen determined to establish a colony on the *Meta Incognita*, as she called the newly-found land, and accordingly, Frobisher again set sail with fifteen ships. A violent storm, however, sunk one of the vessels, and so severely damaged the rest, that all hope of founding the colony was abandoned. After taking on board several hundred tons of the supposed gold-ore, the fleet returned—their ill-success being further aggravated by the information that

the ore was utterly worthless. But the Company still continued the search, as if determined to force the icy barriers of the north, and in 1580 sent out the *George*, under the command of Pet, and the *William*, under the command of Jackman. These two vessels, of only 40 and 20 tons respectively, penetrated some distance into the Kara Sea, but the ice barred further progress. Only one of them returned home, the other having most probably foundered off the coast of Norway. The next expedition to the northern seas sailed in 1583, under Sir Humphrey Gilbert. After founding a colony in Newfoundland, Sir Humphrey proceeded north in the *Squirrel*, accompanied by two other vessels—the *Delight* and the *Golden Hind*. The latter was wrecked off Sable Land, and the other two then turned towards home. In a terrible storm, when near the Azores, the little *Squirrel* and her brave commander and crew perished; the *Golden Hind* with difficulty reached England. The gallant John Davis set out, in 1585, in command of the *Sunshine* and the *Moonshine*, and succeeded in reaching Cape Walsingham. The following year he sailed again north with two additional vessels, and ascended most probably as far as the 80th parallel. In his third voyage he reached Cape Hope Sanderson. Shortly after, George Waymouth and other navigators explored the Greenland Seas, but without positive results.

291. On the 4th of June, 1594, William Barents sailed from the Texel, in command of the *Mercurius*, fitted out by the merchants of Amsterdam. On the 4th of the following month he sighted Nova Zembla, and, doubling Cape Nassau, pushed along the coast as far as the Orange Islands. Here, however, he was stopped by the ice-barrier, and spent several days in searching for an opening, during which he went over "no fewer than seventeen hundred miles of ground, and put his ship about one-and-eighty times."[1] It was, however, all

[1] *The Arctic World* (Nelson).

in vain, and Barents returned home. Two years later the merchants of Amsterdam sent out two other vessels, Barents being ostensibly engaged as pilot. Passing Bear Island, the coasts of Spitzbergen were sighted on the 19th of June. Retracing their way to Bear Island, the vessels separated—one returning to Holland, the other, with Barents on board, proceeding to Nova Zembla. After passing Cape Comfort, the vessel was so hemmed in by the ice that Barents was forced to winter in Ice Haven. For greater safety a hut was constructed on shore, and in this they lived until the 14th of June the year following, when the breaking up of the ice enabled them to set out for Lapland in two boats—their ship being too much damaged by the ice. In forty days the brave Hollanders threaded their way among and across the ice floes for eleven hundred miles, and eventually gained the port of Kola, in Lapland, but the gallant Barents had expired on the 19th of June. The hut in which Barents and his companions had passed the winter was discovered on the 9th of September, 1869, by Captain Carlsen, of the Norwegian sloop *Solid*.[1]

292. We then come to the important discoveries made by the English navigator, Henry Hudson, who, in 1607, coolly determined to sail right across the Polar seas to Japan in a mere "cock-boat"—the *Hopewell*, of 80 tons—with a crew of only twelve men and a boy! Leaving Gravesend on the 1st of May, Hudson sighted Spitzbergen on the 27th of June. Having pushed north fully half a degree beyond the 80th parallel, he returned home, discovering on his way south the solitary islet of Jan Mayen. His second voyage to the north-

[1] "No man had entered the lonely dwelling where the famous discoverer of Spitzbergen had sojourned during the long winter of 1596, for nearly three centuries. There stood the cooking-pans over the fire-place, the old clock against the wall, the arms, the tools, the drinking vessels, the instruments, and the books that had beguiled the weary hours of that long night 278 years ago."—"*Discoveries East of Spitzbergen*," &c. Paper read by C. R. Markham, Esq., C.B., F.R.S., before the Royal Geographical Society, February 10th, 1873. Captain Carlsen removed the relics, and they are now deposited at the Hague.

[2] Originally named *Hudson Sutches*.

east in the following year was equally unsuccessful. His third and last voyage, in 1610, was made in a different direction. During a careful examination of the seas between Labrador and South Greenland, Hudson discovered a wide channel, through which he sailed west, and thus entered the vast inland sea named after him, Hudson Bay. Here his crew mutinied, and the unfortunate navigator, his son, and seven "sicke and lame men," were sent adrift in an open boat, and were never heard of after.

293. Passing over the semi-commercial voyages on account of the Muscovy Company, made in 1611 by Captain Poole, and in 1613 by Captain Joseph, we have the remarkable voyage of Fotherby along the west coast of Spitzbergen in 1614, followed two years after by Baffin in the *Discovery*. Baffin left England on the 26th of March, and sailed north, eventually entering the vast expanse of water now known as Baffin Bay. After reaching the then high latitude of 78° at the entrance to Smith Sound, he turned south, and arrived safely in Dover Roads on the 20th of August. Although the "North Water" discovered by Baffin was found open and navigable during the summer months, no attempt was made to penetrate the Middle Pack that separates it from Davis Strait until 1818, when the English Government sent out an expedition (ostensibly to discover the North-West Passage) under Captain, afterwards Sir John, Ross, who only succeeded in reaching the entrance to Smith Sound. An expressly Polar voyage was also undertaken by Captain Phipps in 1773, with two vessels, the *Racehorse* and *Carcass*;[1] on board the latter of which Nelson served as midshipman. In April, 1818, Captain Buchan and Lieutenant Franklin were sent out in command of the *Dorothea* and *Trent*, but gained no positive results. In May the following year, the British Government equipped the *Hecla* and the *Griper*, and de-

[1] For full particulars of this and other Arctic voyages, see Captain Markham's admirable work, *Northward Ho!* (Macmillan).

spatched them north, with Lieutanant Parry in command. An ice-barrier 80 miles in width, just north of the 73rd parallel, was forced, and Lancaster Sound, Barrow Strait, and Wellington Channel were successively explored. In 1821, Captain Parry again sailed north in the *Hecla*, now accompanied by the *Fury*, and discovered Duke of York Bay, Fury and Hecla Strait, and numerous other channels between the islands west of Baffin Land. Parry's third voyage (1824-25) was unfortunate, but in his fourth voyage he reached the furthest northerly point yet attained, 82° 45′. Meanwhile, in 1822-23, Scoresby and Graah had explored the coast of East Greenland.

294. In 1845, Sir John Franklin in the *Erebus*, and Captain Crozier in the *Terror*, were sent north, with instructions to sail through Lancaster Sound and Barrow Strait to Behring Strait. The two vessels were last seen in June the same year, in Melville Bay. For two years nothing was heard of the expedition; but, incited by the heroic wife of the gallant commander, who believed her husband's vessels were simply hemmed in by the ice, several ships were sent north. The search for the missing vessels was energetically prosecuted, but it was not until 1850 that a clue was found—viz., a cairn and three graves on Beechey Island. One of the vessels—the *Investigator*—engaged in the search, commanded by Capt. M'Clure, entered the Arctic Ocean through Behring's Strait in 1850, but was frozen up in Prince of Wales Strait, whence Melville Sound was seen. "Captain Sir R. M'Clure, by this perilous voyage, prosecuted with undaunted perseverance, found a strait connecting the continental channel with Melville Sound, and thus discovered the *North-West Passage*" (Richardson). The generally ice-bound state of the channels by which the passage might, under unusually favourable conditions, be made, renders the undertaking a most perilous one. *Commercially*, indeed, the brilliant achievement of Captain M'Clure is unimportant, as the channels

he passed through can never be utilised as a waterway between the two great oceans.

295. In 1854, Dr. Rae being informed by the Esquimaux that a party of about forty white men had died from starvation a few years previously, and additional relics of the ill-fated expeditions being found, the search was recommenced. The following year Mr. Anderson, one of the Hudson Bay Company's officers, crossed overland to the mouth of the Great Fish River; and in 1857, Captain, afterwards Sir Leopold, M'Clintock, went out in the *Fox*, and wintered in Bellot Strait, whence sledge-parties explored the adjoining land. On Point Victory a cairn, containing Sir John Franklin's papers, was found. It seems that the expedition, having wintered at Beechey Island, had pushed south towards King William Land, but the ships were beset in the ice, near Cape Felix, in September, 1846. Franklin had died on the 11th of June, 1847; and in April the year following the survivors abandoned the ships, and started overland for the Great Fish River. A few reached the mainland, but not one lived to tell the tale.[1] It thus appears that the honour of discovering the North-West Passage is due to the unfortunate Franklin. *Ninety miles more of open water would have enabled him to carry his vessels into the open Arctic Sea.* But "it was not to be so. Let us bow in humility and awe to the inscrutable decrees of that Providence who ruled it otherwise. They were to discover the great highway between the Pacific and the Atlantic. It was given them to win for their country a discovery for which she had risked her sons' sons, and lavished her wealth through many centuries; but they were to die in accomplishing their last great earthly task; and, still more strange, but for the energy and devotion of the wife of their chief and leader, it

[1] The MSS. said to be found in Hudson Bay, purporting to have been written by a survivor of the Franklin expedition, and containing an ingenious account of the discovery of inhabited lands at the North Pole, is evidently a *canard*, far less credible than the proverbial sailor's "yarn."—*Vide* Whymper's "*Arctic Heroes.*"

would in all probability never have been known that they were indeed the *first discoverers of the North-West Passage.*"

296. The American Expedition, under the brave Dr. Kane, sailed from Boston in 1853, and wintered in Rensslaer Bay, on the eastern side of Smith Sound, whence sledge-parties pushed to the north. Dr. Kane personally approached the Great Humboldt Glacier, and Dr. Hayes explored the opposite coast of Grinnel Land as far as Cape Fraser. Morton, with another party, reached the shores of an open sea, perfectly free from ice. The *Advance* was abandoned on the 28th of May, and the explorers ultimately reached Uppernavik, whence they sailed for New York. In 1860, Dr. Hayes proceeded north in the *United States*, following the usual route through Smith Sound. The probability of reaching the Pole by the Spitzbergen route led to the despatch of the *Germania* and the *Hansa* from Bremerhaven, in June, 1869. Both vessels struck the ice a little north of the 74th parallel, and on the 20th of July, owing to the commander of the *Hansa* mistaking the signal ("come close") from the *Germania*, the ships parted company. The *Hansa* stood west towards East Greenland, but being caught in an ice-floe, the pressure was so great that she sank on the 22nd October—the officers and crew taking refuge in a coal hut, which had been erected on the floe.[1] Thus situated, they drifted south for nearly 200 days, but ultimately managed to land on a small island off the Greenland coast, whence they set out for the mission station of Friedrichsthal, in South Greenland, which was reached with great difficulty. Meanwhile the *Germania* was frozen in on 16th September. A sledge-party reached the furthest northerly point, 77° 1′. On the 15th of April the following year, the *Germania* was freed from the ice, and steamed north for some distance; but, besides the partial exploration of the remarkable East Greenland fiord, in lat. 73° 13′ N., nothing further was done, and the vessel returned to Bremen. The

[1] This floe was 7 miles long, and about 2 miles across.

Polaris, with Captain Hall in command, was sent out by the American Government in 1871. Entering Smith Sound, Hall pushed across Kane Sea and Kennedy Channel, reaching, in Robeson Channel, the latitude of 82° 16′ N. on the 30th of August. The expedition wintered in Thank God Harbour, whence the *Polaris* sailed south on the 12th of August, 1872, but was again caught in the ice, and driven ashore at Lyttleton Island, where she was abandoned. Her crew managed to reach Melville Bay, where they were picked up by a whaler.

297. Captain Johannsen, in 1870, successfully circumnavigated Nova Zembla—a feat which was repeated the following year by Captain Carlsen, who, as we have already mentioned, discovered the hut in which Barents and his companions had passed the winter of 1596-7, and which had not been visited for 278 years. The many interesting relics of the old navigators were ultimately purchased by the Dutch Government. In the same year Weyprecht and Payer, in a small yacht, the *Isbjorn*, reached a point 78° 38′ N. lat. In this high latitude Payer reported that the ice presented no serious impediment, and the probability of success in that direction, by a larger vessel provided with steam-power, led to the despatch of the Austro-Hungarian Expedition of 1872. The *Tegetthoff* left Tromso on the 13th of July, and on the 29th the coast of Nova Zembla was sighted. The *Isbjorn*, which had arrived on the 12th of August, left shortly after, and the *Tegetthoff* then steamed north, but was beset in the ice on the 20th, and drifted helplessly north, until, on the 30th of August in the year following, a high rocky coast was approached, in latitude 79° 43′ N., long. 59° 33′ E. The explorers succeeded in landing twice, on the 1st and 3rd of November the same year, but it was not until the following year that the newly-discovered land, named after the Austrian Emperor, *Franz Joseph Land*, was explored. The sledge party under Payer set out in March, and reached their highest point in 82·5° N. lat., after a march of 17 days from the ship,

which was enclosed in ice in 79·51° N. lat. They returned to the ship on the 3rd of May, but as there was no probability it would ever be free from the ice, it was resolved to abandon her, and to return south in sledges and boats. After a most adventurous, and at first especially toilsome and difficult journey, the Bay of Dunes was reached in safety on the 24th of August. Here they were taken on board a Russian schooner, and landed at Vardo on the 3rd of the following month, after an absence of over 800 days.

298. We now come to the British Arctic Expedition of 1875-6. The *Alert* and *Discovery*, with Captain, now Sir George, Nares in command, left Portsmouth on the 29th of May, 1875, accompanied by H.M.S. Valorous with coal and provisions, sailed through Davis Strait and Baffin Bay into Smith Sound, and eventually both vessels pushed north through Kennedy Channel to the northern extremity of Robeson Channel, where they wintered. The *Discovery's* winter quarters were on the northern side of Lady Franklin Sound, in latitude 81° 44′ N. The *Alert* pushed further north, but being hemmed in by the ice-barrier, was forced to take shelter inside a line of stranded floes on the western side of Robeson Channel, in latitude 82° 27′ N., 11′ further north than the Polaris in 1872. Sledge-parties were sent out in the spring of 1876. (1) Lieutenant Aldrich, and a sledge crew under Lieutenant Giffard, explored the shores of Grant Land, reaching C. Columbia, the most northerly point, on the 1st of May, and seventeen days later the furthest westerly point, 82° 16′ N. lat., and 85° 33′ W. long., was attained. (2) Commander Markham, with Lieutenant Parr second in command with two boats and three sledge crews under Drs. Moss and White, started with Aldrich's party, and separating on the 11th of April at Cape Joseph Henry, Markham and his companions pushed north over the frozen sea for 40 days, reaching on May 12th the *furthest northerly point* yet attained, in latitude 83° 20′ 26″ N., only four hundred miles from the

North Pole. On the following day they turned south, and with great difficulty reached the *Alert* on the 14th of June. (3) Lieutenant Beaumont's sledge-party left the *Discovery* on the 6th of April, reaching the *Alert* on Sunday the 16th. On the 20th of the same month, Beaumont, accompanied by Lieut. Rawson and Dr. Coppinger, with 21 men and four sledges, started for Greenland. The furthest easterly point, lat. 82° 20′ N., 51° 30′ E. long., was reached on the 21st of May, and the party returned to Discovery Bay on the 15th of August.

299. On the 31st of July the *Alert* was freed from the ice, and joined the *Discovery* on the 12th of the following month. After a most hazardous voyage down Kennedy Channel and Smith Sound, open water was reached near Cape Isabella. The expedition ultimately arrived in safety in Portsmouth Harbour on the 2nd of November, having indeed failed to reach the North Pole, but having proved that the land between the meridians of 50° and 85° W. extends no further than about 83° N. lat.—the coasts of Greenland trending away north-east to Cape Britannia, while those of Grant Land run almost due west along the 83rd parallel from 70° to 80° W. long., and thence curve south-west. Two vast inlets from Hall Basin were also explored,—Petermann Fiord on the Greenland side, and Lady Franklin Sound, with Archer Fiord, on the opposite side. This expedition definitely proved the utter impossibility for any vessel to penetrate the "Palæocrystic Sea,"[1] as that part of the Polar Ocean north of Robeson Channel is called, and that the most energetic sledging parties can never hope to reach a much higher latitude than that attained by Commander Markham, and that the primary object of all directly Polar expeditions—reaching the North Pole—can never be realised by the Smith Sound route. Admiral Richards says that "the Pole must be sought by ship alone, and by the only track which has not

[1] *i.e.*, Sea of ancient ice.

yet been found impossible for steam to penetrate—by the Sea of Spitzbergen."

[Along the 300 miles of coasts examined by the sledging parties under Lieutenants Beaumont and Aldrich, the ice was of the same character as that immediately north of the *Alert's* winter quarters. It was from 80 to 100 feet thick, and apparently of great age. Although subject to an annual disruption, the increase during the winter exceeds the decay during the summer. Sir Rutherford Alcock, in his address to the Royal Geographical Society, at the anniversary meeting on the 28th May, 1877, said that "Careful and diligent observation furnished some data by which a judgment might be formed of the probable extent of the Palæocrystic Sea. It is certain that land was not near to the north, because hills were ascended to a height of 1,500 feet and upwards on clear days, and there was not a sign of land. But there are other considerations all tending to the same conclusion. There are no flights of birds to the north, which certainly would be the case if there was land; and the only living thing that was seen on the Palæocrystic Sea by the northern division of sledges was a little snow-bunting that had strayed from the nearest shore. Further evidence is furnished by the fact that marine animal life almost ceases to exist in the ice-covered Polar Sea. The Palæocrystic Sea is a sea of solitude."]

300. Of the various attempts made to discover the *North-East Passage*, those of Willoughby in 1553, Burrough in 1556, Pet and Jackman in 1580, Barents in 1594-7, and Hudson in 1608, have been already noticed. The Danes made another attempt in 1653, the English in 1676, both equally unsuccessful in penetrating the ice-barrier north of Nova Zembla. A Dutchman, Cornelius Roule, is said to have sailed in 1698 due north of Nova Zembla as far as the 85° parallel, where he discovered land. If so, the honour of discovering Franz Joseph Land is due to the adventurous Roule.[1] The maritime nations of Western Europe then relinquished the exploration

[1] See an able paper on *The Arctic Campaign of* 1879 *in the Barents Sea:* by Captain A. H. Markham, R.N., read at the Meeting of the Royal Geographical Society, Nov. 24th, 1879.

of the apparently impenetrable north-eastern seas. Russian navigators, however, took up the matter energetically; as many as eighteen expeditions successively explored the coasts of Nova Zembla and Siberia, none of which, however, succeeded in solving the problem of a north-east passage. Nova Zembla was first circumnavigated in 1760 by Sawwa Loschkin, and eight years later a Russian vessel passed through the deep inlet across Nova Zembla known as the Matyushin Shar. The Russian Government fitted out the *Novaya Zemlya* in 1821, and for four years its commander, Lutke, explored the west coast of the island. Other expeditions were sent out, but no material progress was made until the cruise of the *Ibsjorn* in 1871, and the *Tegetthoff* in 1872-4.

301. Professor Nordenskiold having explored Spitzbergen, decided to push eastwards through the Kara Sea, and left Tromsoe in the *Proeven*, in June, 1875. In the following month he sailed through the Matyushin Shar in Nova Zembla, to the mouth of the Yenesei, on the north side of which the Swedish flag was hoisted on the 15th of August. In 1876 the Professor made a second voyage to the Yenesei in a small steamer, the *Ymer*, returning to Tromsoe on the 22nd of September. The now famous *Vega*, accompanied by the *Lena*, started from Tromsoe on the 21st of July, 1878, and, sailing through Mageröe Sound, safely doubled the northernmost point of the Old World—Cape Chelyuskin, or North-East Cape. On the night of the 27th of August the *Lena* left for Fadayev. The *Vega*, steering still east, was so beset by the ice, that Nordenskiold was forced to winter on the Siberian coast, near Sardre Kamen, only 130 miles from the northern entrance of Behring's Strait. After a detention of 294 days—from the 28th of September, 1878, to the 18th of July, 1879—the *Vega* resumed her voyage, entering Behring's Strait on the 20th of July. "Now at last the goal was reached for which so many nations had striven, ever since Sir Hugh Willoughby, on the 20th May, 1553, sailed

from Greenwich in command of three vessels—the *Esperanza*, *Edward Bonadventure*, and *Bona Confidentia*—upon a voyage of discovery in the North Sea. Many other expeditions from different countries have started on the same errand, always without success, and often with the loss of ships and many brave sailors. After the lapse of 326 years, and after the most experienced seafaring men had declared the undertaking to be an impossibility, the *North-East Passage* has at last been accomplished without the loss of a single life, without a case of sickness amongst those who shared in the enterprise, and without the slightest damage to the vessel. It was also effected under circumstances which prove that the feat can be repeated in most years, perhaps every year, and within the space of a few weeks."[1] On the 22nd of July the *Vega* dropped anchor in Port Clarence, on the eastern side of Behring's Strait. After visiting St. Lawrence and Behring Islands, all sail was made for Japan; and on the 2nd of *September* the *Vega* anchored in the roadstead of Yokohama, whence she returned to Europe.

[In a memorandum addressed to the King of Sweden, Professor Nordenskiöld thus sums up his opinion as to the regular navigation of the Arctic Ocean along the Siberian coast:—

"1. The route by sea from the Atlantic to the Pacific on the northern coast of Siberia may be frequently traversed in a few weeks by a suitable steam vessel, manned by experienced sailors; but it is not likely, from the acquaintance which we now have with the glacial sea of Siberia, that this route will become in its entirety of substantial importance to trade.

"2. We may now assume that no difficulty exists for the utilisation, as a commercial route, of the sea voyage between Europe and the mouths of the Obi and Yenesei.

[1] *Proceedings of the Royal Geographical Society*. Vol. II., No. 1. January, 1880. Nordenskiold adds—"We may be pardoned if, under these circumstances, we saw with a certain amount of pride our blue-and-yellow flag go up to the masthead, and heard the Swedish salute in that Strait where the Old and the New World seem to shake hands."

"3. In all probability the sea-route between the Yenesei and the Lena, and between the Lena and Europe, may be also used as a commercial route, but it will not be possible to go to the Lena and to return to Europe in the same summer.

"4. Further explorations are necessary in order to decide on the possibility of opening out commercial maritime relations between the mouth of the Lena and the Pacific. The experience acquired by the expedition shows that it is possible to bring by this route from the Pacific into the basin of the Lena, steam vessels, heavy engines, and other articles which cannot be conveniently transported on sledges or by wheel conveyance."

Of the minor expeditions, most important results have been gained by the gallant Dutch explorers on board the *Willem Barents*, a small sailing-vessel which has thrice (1878-79-80) visited the north-eastern seas. The Bennett Expedition to the Arctic regions left San Francisco on the 8th July, in the *Jeanette*. Nothing has yet (Jan. 1881) been heard of the vessel, but little anxiety is felt for its safety. During the summer of 1879 the cutter *Isbjörn*, with Sir Henry Gore Booth and Captain A. H. Markham, pushed north between Spitzbergen and Nova Zembla, as far as 70° 24′—only 80 miles from Franz Joseph Land. Last year (1880) Mr. Leigh Smith, in a steam-yacht, the *Eira*, reached and explored the south-western coasts of Franz Joseph Land. Having taken his vessel as far as 80° 20′ N. lat., he returned, and arrived safely at Peterhead on the 12th of October.]

APPENDIX A.

Changes in the Distribution of Land and Water.

The geological parallelism between islands and the adjacent mainland go far to prove that they must at one time have been connected by dry land. Thus Great Britain was evidently a part of the continent at a geologically recent period. Recent soundings in the seas which encompass the British Isles, show that they are but the higher elevations of a submarine plateau, extending from France to Norway. That the North Sea is not a true oceanic depression will be seen from the fact that, were a fall of 60 feet to take place in the level of the sea, the well-known "Dogger Bank" would become visible, while if it fell 100 fathoms, or 300 feet, the German Ocean, English Channel, the Irish Sea and connecting channels, and a belt of about 50 miles in width, west of Scotland, Ireland and France, would become dry land.

And as the mean elevation of the land above the sea-level is 200 fathoms, or, if we exclude the principal mountain chains and tablelands, only 100 fathoms, we may imagine what would be the effect of a general rise of the sea to 100 fathoms above the present level, or a general subsidence of the land to the same degree. All the plains and lower-lying lands of the globe would disappear beneath the waters, leaving only the higher mountains and more elevated plateaux visible. A glance at the contour-map of the ocean which forms the frontispiece of this work, will show that the highest portions of land are not contiguous to the deepest parts of the ocean, nor does there seem to be the least connection between the two, except, perhaps, as regards absolute height, in which respect a very striking resemblance has been observed. The highlands of the globe approximate to the Indian Ocean in the Old World, and to the Eastern Pacific in the New, but the great oceanic depressions are found in the Western Pacific, north of the equator, and, with one exception, in the Western Atlantic.

APPENDIX B.

On the Distribution of Temperature in the Atlantic Ocean.

Sir C. Wyville Thomson thus sums up the general facts and conclusions with regard to the distribution of temperature in the Atlantic :—

1. "That the Atlantic must be regarded in the light of an inlet or gulf of the general ocean of the water-hemisphere, opening directly from the Southern Sea.

2. "That the water of the Southern Sea simply wells up into the Atlantic, and that all the temperature bands of the Atlantic are essentially continuous with like temperature bands in the Southern Sea, with these modifications:—That (*a*) above a certain line, which may be roughly represented by the isothermobathic lines of 5° and 4° C., the temperature of the water is manifestly affected by direct radiation, and by the very complicated effects, both direct and indirect, of wind currents; and (*b*) that the whole mass of the water gradually and uniformly rises in temperature towards the head of the gulf.

3. "That water at any given temperature (below 4° C.) can only occur in the Atlantic where there is a direct communication with the belt of water at the same temperature in the Southern Sea, without the intervention of any continuous barrier. (The actual result of the present arrangement of such barriers is, that however great the depth may be, no water at a temperature lower than 1°.9 C. is found in the eastern basin; none at a temperature lower than 1°.6 C. in the north-western; and none beneath the freezing-point anywhere in the Atlantic, except in the depression between the coast of South America and the central ridge, to the south of the equator).

4. "That the temperature of the Atlantic is not sensibly affected by any cold indraught from the Arctic Sea, (I purposely neglect the Labrador current, and the small branch of the Spitzbergen current, for these certainly do not sensibly affect the general temperature of the North Atlantic).

5. "That although there is a considerable flow of surface water, through the influence of wind-currents, from the Atlantic into the Southern Sea, that flow is not sufficient to balance the influx into the basin of the Atlantic (the constant influx being proved, by the maintenance of a general uniformity in the course of the isothermobathic lines, and by the maintenance in all the secondary basins of the minimum temperature due to the height of their respective barriers); that for several reasons (the lower barometric pressure, and the supposed greater amount of rainfall in the Southern Sea; the higher specific gravity at the surface than at greater depths in the Atlantic; the higher specific gravity of the surface-water in the Atlantic to the north than to the south of the equator) it is probable that the general circulation is kept up chiefly by an excess of evaporation in the region of the North Atlantic, balancing a corresponding excess of precipitation over evaporation in the water-hemisphere."

NOTE.—For a clear description of the "Nature of Wave-motion," see pp. 35-37, in Piper's *Acoustics, Light and Heat*. Full particulars of "Winds and Storms" will be found in pp. 136-162, Hughes's *Physical Geography*. [G. Philip and Son].

INDEX.

*** *The figures refer to the paragraphs of the text.*

Adelie Land 263
Agulhas current 125
Alert 277
Antarctic drift-current 263
——— Ocean, 19, 27; generalities, 261-265; historical notes 266
Apparatus, Brook's Sounding, 75; Sir William Thomson's .. 76
Arctic current 184
——— Ocean, 18, 27; generalities, 276; historical notes, 288; river-system 33
Atlantic Ocean, 15, 21-24; depth and bed, 186-188; navigation and commerce, 189-191; historical notes 192-200
——— river-system 34
Attraction of gravitation, 116; solar and lunar, 117, *et seq.*
Aurora Australis 270
——— *Borealis* 286
Azov, Sea of 210
Baltic Sea 202-205
Beaches, raised 205
Biscoe's voyage 270
Black Sea 210
Bore 122
Bottle, cruise of a, (note) 185
Bottom-ice, formation of 205
Bottom-temperature 102
Boundaries of Atlantic, 153; Indian Ocean, 239; Pacific .. 212
Brazil current 185
Breezes, land and sea 139
Buchanan, Mr. J., 54; footnote 59
Cape Horn current 227
Caspian Sea 211
Challenger Expedition, 54, 78, 85, 186, 199, 230, 238, 253
Challenger ridge 188
Circulation, oceanic 125, 127
Climate, influence of sea on ..133-145
Coast, form of, relation to depth of water 86-87
Coasts of Atlantic 170-175
——— Indian Ocean 248
——— Pacific 222, 223
Cohesion of water 45
"Cold Wall" 104, 179
Columbia, Cape 279
Columbus 195
Commerce of States bordering on Atlantic 190
Constant currents 124
Continental climate 144
Cook's voyages..... 238, 267, 268
Currents, ... 123
——— classification of ..124, —
——— of Atlantic 178-185
——— of Indian Ocean ..249-251
——— of Mediterranean .. 207
Davis Strait current 184
Deep-sea currents 124
Definitions 4-7
Density—greatest density of water 63
Denudation, marine, instances on British coasts.....153, 154
Discovery, progress of 39-44
Dolphin ridge 188
Drainage area of Atlantic 176
——— Pacific 224
Drake, Admiral 237, 260
Drift, Antarctic 250
Drift-currents 124
Earth's crust, action of the sea on the 146-157
East Australian current 227
—— Greenland current 184
Equatorial counter-current 227
——— current 125
Erythræum sea..... 258
Extent of Atlantic 161
——— Indian Ocean 239
——— Pacific 212
Extreme climate 144
Firth, fiord 5
Fleet, first English..... 193

Floe-bergs 237
Gazelle 230, 238, 253
Gettysburg, U.S.S. 200
Glaciers 287
Guiana current 179
Guinea current 125, 180
Gulf stream 125, 178-183
Haffs 170, 204
Hemispheres, distribution of land in 8-13
——— continental and oceanic 10
Hummocks 287
Icebergs ..... .263, 287
Indian Ocean, 17, 26; navigation and commerce, 255; river-system 38
Insular climate 144
Intercommunication, Oceanic, 20; Atlantic, 21-24; Pacific, 25; Indian Ocean, 26; Arctic and Antarctic 27
Islands of Atlantic, 162-164; Indian Ocean, 242; Pacific, 216, 234
Japanese current 125, 227, 228
Kuro-Siwo 228
Labrador current 184
Landes (footnote) 172
Life, animal, in South Polar regions 265
Life, distribution of marine, 92; vegetable, 93-94; animal 95-99
Lightning and *Porcupine* Expedition 199
Lym Fiord (footnote) 170
Magellan 23, 259
Marine débris, drifting of 128
Maritime climate 144
Mediterranean Sea 206
Mentor's current 229
Mexican current 125, 228
Movements, atmospheric, 108-114; sidereal, 115-122; proper 123-144
Mozambique current 251
Names of Oceans, derivations of (note) 19
Navigation 39
Nehrungs 204
Nordenskiold, Prof. 301
North African current 180
North-East Passage, 169, 221, 300, 301
North-West Passage 169, 221
Ocean currents, temperature, 136; velocity 137
Ocean, the depth of, 79; general geography, 1-44; physical geography, 45-157; pressure and weight of the, 81-84; temperature of, 100; movements .. 106
Ophir 257
Pacific Ocean, 16, 25; basins of, 231; navigation and commerce, 232; historical notes, 235-238; river-system 37
Periodical currents 124
Peruvian current 125, 227
Phosphorescence 66
Polar water, influx of 133
Polo, Marco 235
Red Sea, salinity, &c. 50
Reef, Gt. Barrier 223
Relative areas — northern and southern hemispheres, 8; eastern and western, 9; continental and oceanic, 10; in zones 12
Rennell's current 179
River systems — Oceanic, 28; Arctic, 33; Atlantic, 34, 176; Pacific, 37, 224; Indian, 38, 243-247
Rotation, influence of earth's, 134, 135
Saltness — areas of maximum, 48; minimum 51
Salts of the sea—origin of, 54; results of 59-60
Sargasso Sea 65, 180
Sea, the action of the, on the earth's crust 146-157
—— colour, 64; phosphorescence 66
—— curvation of the, 46; salts of 47
Sea-bottom, form of 85-91
Sea-level 2, 45
Seas and inlets—Atlantic, 165-166; Indian Ocean, 240; Pacific 218-221
Sea water, composition of 47-52
——— density of 61
Skerki shoals 208
Snowline, Antarctic regions .. 265
Soundings, deep-sea 68-76
Sounding machine — Sir W. Thomson's improved 76
Southern connecting current 185-251
Southern Ocean, the 14, 261
South Shetlands 269
Specific gravity of sea-water .. 61
Subsidence of South Sweden .. 205

GEORGE PHILIP AND SON, PRINTERS, CAXTON BUILDINGS, LIVERPOOL.

PHILIPS' EDUCATIONAL CATALOGUE.

ATLASES.

The Training College Atlas.

A Series of Twenty-Four Maps, illustrating the

PHYSICAL AND POLITICAL GEOGRAPHY

Of the Chief Countries of the World. Originally Designed and Drawn by W. Hughes, F.R.G.S. *New and enlarged edition*, extended and completed by E. G. Ravenstein, F.R.G.S. Medium folio, cloth lettered, 18s.

*** The "Training College Atlas" is a work altogether distinct in character from any previously published. In its production the Publishers have aimed at combining the *fullest and most recent physical and political information* with the *greatest possible clearness and distinctness*, and it is believed that the new Atlas will be found to possess both these important features in a higher degree than any yet issued.

"It would be difficult, if not impossible, to supersede this really handsome and serviceable Atlas, which we think the best of the many successful efforts which Messrs. Philip and Son have yet put forth as geographical publishers."..... —*The School and University Magazine.*

"Amongst the many excellent Atlases which are now available for use, we are disposed to give a high place to the 'Training College Atlas.' .....All the recent political changes in different parts of the world are carefully represented."—*School Guardian.*

....."The fullest information is given, consistently with remarkable distinctness and even beauty of execution, and with no more trouble to the Student than that of mere inspection."....—*The Bookseller.*

Philips' Comprehensive School Atlas

Of Ancient and Modern Geography, with Index. Edited by W. Hughes, F.R.G.S. New and improved edition. Imperial 8vo, strongly half-bound, 10s. 6d.

Philips' Student's Atlas,

Comprising Thirty-eight authentic Maps of the Principal Countries of the World, with Index. Edited by William Hughes, F.R.G.S. Imperial 8vo, strongly bound in cloth, 7s. 6d.

Philips' Select School Atlas,

Comprising Twenty-four authentic Maps of the Principal Countries of the World, with Index. Edited by William Hughes, F.R.G.S. Imperial 8vo, new and cheaper edition, strongly bound in cloth, 5s.

Philips' Introductory School Atlas,

Comprising Eighteen Maps of the Principal Countries of the World with Index. Edited by William Hughes, F.R.G.S. New and cheaper edition. Imperial 8vo, cloth, 3s. 6d.

Philips' Young Student's Atlas,

Comprising Thirty-six Maps of the Principal Countries of the World Edited by W. Hughes, F.R.G.S. Imperial 4to, cloth, 3s. 6d.

Philips' Young Scholar's Atlas,

New and enlarged edition, containing Twenty-four Maps. Edited by W. Hughes, F.R.G.S. Imperial 4to, 2s. 6d.

Philips' Atlas for Beginners,

Comprising Thirty-two Maps of the Principal Countries of the World with Index. New and improved edition. Edited by W. Hughes, F.R.G.S. Crown 4to, cloth, 2s. 6d.

Philips' Handy Atlas of General Geography,

Containing Thirty-two Maps, with a Consulting Index. Edited by William Hughes, F.R.G.S. Crown 8vo, cloth, 2s. 6d.

Philips' Shilling Atlas of Modern Geography,

Containing Twelve Imperial Quarto Maps. 1s.

Philips' First School Atlas.

New and enlarged edition, containing Twenty-four Maps. Crown 4to, 1s.

Philips' Preparatory Atlas,

Containing Sixteen Maps, full colored. Crown 4to, in neat cover, 6d.

Philips' Elementary Atlas for Young Learners.

Sixteen Maps. Small 4to, in neat cover, 6d.

Philips' "Standard" Atlas.

Prepared to suit the Higher Standards (New Code). Foolscap 4to, 6d.

Philips' Initiatory Atlas for Young Learners.

Containing Twelve Maps. Imp. 16mo, 3d. Colored, 6d. Ditto, cloth, 1s.

Philips' Atlas of the British Colonies,

Containing Sixteen Maps, including a Map of the British Empire throughout the World, colored so as to shew the whole of the British Possessions at one view. Crown 4to, in neat cover, 6d.

Philips' Atlas of the Countries of Europe,

Including a Map of the World and a General Map of Europe. Crown 4to, 6d.

Philips' Atlas of Wales,

Comprising Twelve Maps of the Separate Counties. Crown 4to, 6d.

Philips' Atlas of the British Empire throughout the World,

A Series of Twenty-three Maps, with explanatory and statistical Notes, by John Bartholomew, F.R.G.S. Imp. 8vo, bound in cloth, 3s, 6d.

Philips' School Atlas of Australia,

Comprising Maps of the separate Colonies, including a General Map of Australia, and Maps of New Zealand and Tasmania. Crown 4to, cloth, 2s.

Philips' School Atlas of New Zealand,

Comprising Eleven Maps. Crown 4to, bound in cloth, 2s.

Philips' Physical Atlas for Beginners,

Comprising Twelve Maps. New and cheaper edition. Crown 4to, stiff cover, 1s. Cloth lettered, 1s. 6d.

*** This Atlas is intended to accompany "Philips' Elementary Class-Book of Physical Geography."

Philips' School Atlas of Physical Geography,

Comprising a Series of Maps and Diagrams illustrating the Natural Features, Climates, Various Productions, and Chief Natural Phenomena of the Globe. Edited by W. Hughes, F.R.G.S. Imperial 8vo, strongly bound in cloth, 10s. 6d.

*** This Atlas is intended as a companion volume to Hughes's "Class-Book of Physical Geography."

Philips' School Atlas of Classical Geography,

A Series of Eighteen Maps, with Index. Medium 4to, cloth, 5s.

Philips' Handy Classical Atlas,

A Series of Eighteen Maps. Medium 8vo, cloth lettered, 2s. 6d.

Philips' School Atlas of Scripture Geography,

A Series of Twelve Maps. New and cheaper edition. Crown 4to, in stiff cover, 1s. Cloth lettered, 1s. 6d. With a valuable Consulting Index, and strongly bound in cloth, 2s. 6d.

Philips' Smaller Scripture Atlas,

Containing Twelve Maps. Imperial 16mo, illustrated cover, 6d. Cloth lettered, 1s.

EDUCATIONAL MAPS.

Philips' Series of Large School-room Maps,

With the Physical Features boldly and distinctly delineated, and the Political Boundaries carefully colored. Size—5 feet 8 inches by 4 feet 6 inches. Constructed by William Hughes, F.R.G.S. Mounted on rollers and varnished, 16s.

LIST OF THE MAPS.

Price Sixteen Shillings each.

The World in Hemispheres.
Europe.
Asia.
Africa.
North America.
South America.
Australia and New Zealand.
New South Wales.
England and Wales.
Scotland.
Ireland.
Palestine.
India.

Price Twenty-one Shillings each.

The World, on Mercator's Projection.
The British Islands.
New Zealand.
Oceania.

Supplementary Maps to the Series.

School Wall Map of the World, on Gall's Cylindrical Projection. Drawn and engraved by J. Bartholomew, F.R.G.S. Size—4 ft. 6 in. by 4 ft. 7 in. Mounted on rollers and varnished, £1 5s.

Philips' Industrial Map of England and Wales, with part of **Scotland;** showing the Lines of Railway, the Seats of the Principal Manufactures, and the Districts of Mines and Minerals; distinguishing Canals and Navigable Rivers, tracing the Tracks of Foreign and Coasting Steam Vessels, marking the Position of Lighthouses, &c. Constructed from the most authentic sources and revised by William Hughes, F.R.G.S. Size—6 ft. by 4 ft. 9 in. Mounted on rollers and varnished, £1 5s.

Philips' Smaller Series of School-room Maps.

Size—3 ft. by 2 ft. 6 in. Mounted on rollers and varnished, each 7s. 6d.

LIST OF THE MAPS.

Eastern Hemisphere
Western Hemisphere
Europe
Asia
Africa
North America
South America
Australia
New Zealand
England and Wales
Scotland
Ireland
Palestine
Wanderings of the Israelites

The above are reductions of the large series, constructed by William Hughes, F.R.G.S., and are designed for use in Private Schools and Families. They are clearly and distinctly engraved, and embody an amount of information not to be had in any similar series of Maps.

PHILIPS' SCHOOL-ROOM MAPS OF THE COUNTIES OF ENGLAND.

Prepared expressly for use in Public Elementary Schools, to meet the requirements of Standard III. of the New Code. Reduced from the Ordnance Survey.

Constructed by John Bartholomew, F.R.G.S.

MAPS ALREADY ISSUED.

Lancashire and Cheshire. Size—5 feet 8 inches by 4 feet 6 inches. Scale—1⅔ mile to 1 inch. Mounted on rollers and varnished, 16s.

Lancashire. Size—37 inches by 54 inches. Scale—1⅝ mile to 1 inch. Mounted on rollers and varnished, 10s. 6d.

Yorkshire. Size—37 inches by 54 inches. Scale—3 miles to 1 inch. Mounted on rollers and varnished, 7s. 6d.

Cheshire. Size—33 inches by 44 inches. Scale—1⅝ mile to 1 inch. Mounted on rollers and varnished, 7s. 6d.

Staffordshire. Size—35½ inches by 54 inches. Scale—2½ miles to 1 inch. Mounted on rollers and varnished, 12s.

Lincolnshire. Size—35½ inches by 54 inches. Scale—1¾ mile to 1 inch. Mounted on rollers and varnished, 12s.

Northumberland. Size—30 inches by 42 inches. Scale—2 miles to 1 inch. Mounted on rollers and varnished, 7s. 6d.

Nottinghamshire. Size—30 inches by 42 inches. Scale—1¼ mile to 1 inch. Mounted on rollers and varnished, 7s. 6d.

Durham. Size—30 inches by 42 inches. Scale—1½ mile to 1 inch Mounted on rollers and varnished, 7s. 6d.

Warwickshire. Size—30 inches by 42 inches. Scale—1¼ mile to 1 inch. Mounted on rollers and varnished, 7s. 6d.

Derbyshire. Size—30 inches by 42 inches. Scale—1½ mile to 1 inch. Mounted on rollers and varnished, 7s. 6d.

Kent. Size—30 inches by 42 inches. Scale—2 miles to 1 in. Mounted on rollers and varnished, 7s. 6d.

Middlesex. Size—5 feet 8 inches by 4 feet 6 inches. Scale—2 inches to 1 mile. Mounted on rollers and varnished, £1 1s.

*** Other Counties in preparation.

DIAGRAMS, &c.

Tablet Lessons,

For the use of the School-room or Nursery. The Set, comprising 1 royal broadside sheets, in cover, with millboard back and woode ledge to hang up, 3s. 6d. The separate sheets, each 2d.

Philips' School-Room Wall Sheets of Multiplication Tables, Numbers, Pence, and Shillings.

Intended for use in National and Board Schools. Size—5 feet 4 inche by 4 feet 6 inches. Mounted on rollers and varnished, each 15s.

No. 1, from One to Twelve times. | No. 2, from Thirteen to Twenty times.

Philips' Diagrams of the Synoptical Tables of the Metri System of Weights and Measures,

With their English Equivalents. Size—44 inches by 33 inche Mounted on rollers and varnished, each 7s. 6d.

A Hand-Book of the Metric System.

Companion to the above. By W. Rickard, LL.D. 6d.

Philips' Diagram of Geographical Terms,

Pictorially illustrating the terms used in Geography. Size—36 in. b 27 in. Mounted on rollers and varnished, 5s.

Philips' Music Sheets,

For use in connection with Taylor's "Manual of Vocal Music," and fo general purposes of Musical Instruction. Printed in two colors Size—33 inches by 44 inches. The set of 15 sheets complete £1 10s.; or mounted on cloth, with wooden ledge at top, £2 12s. 6d Separate sheets, unmounted, 2s. 6d. Ditto, mounted on cloth, 4s Ditto, mounted on rollers and varnished, 5s.

These Sheets, which are unique of their kind, proceed in order from the earlies rudiments, and afford material for the full explanation of any musical passage.

SCRIPTURE PRINTS FOR SCHOOLS AND FAMILIES.

The set comprises 36 Prints, beautifully printed in Oil Colors, with Texts in Ornamental Borders. Size—17 inches by 13 inches. In Neat cover, 15s. The separate Prints, each 6d.

Complete List on application.

PHILIPS'

ELEMENTARY AND ADVANCED

SERIES OF CLASS BOOKS.

READING.

PHILIPS' SERIES OF READING BOOKS,

FOR USE IN

PUBLIC ELEMENTARY SCHOOLS.

Edited by JOHN G. CROMWELL, M.A.,

Principal of St. Mark's College, Chelsea.

Specially adapted to meet the requirements of the New Code.

		S.	D.
PRIMER	80 pp., strongly bound in cloth	0	6
FIRST BOOK—Part I.	96 pp., strongly bound in cloth	0	6
FIRST BOOK—Part II.	96 pp., strongly bound in cloth	0	6
SECOND BOOK	160 pp., strongly bound in cloth	0	9
THIRD BOOK	208 pp., strongly bound in cloth	1	0
FOURTH BOOK	288 pp., strongly bound in cloth	1	4
FIFTH BOOK	320 pp., strongly bound in cloth	1	9
SIXTH BOOK	352 pp., strongly bound in cloth	2	0
POETICAL READING BOOK	352 pp., strongly bound in cloth	2	6
FIRST POETICAL BOOK	160 pp., strongly bound in cloth	1	0

The Present entirely New Series of Reading Books has been prepared with much care and labour under the personal supervision of the Editor; and it is believed everything has been done which experience in teaching could suggest to adapt them to the educational requirements of the present time.

The special aim of the Publishers has been to produce thoroughly good and durable books; they direct the attention of Teachers and School Managers to the *strength of the sewing and firmness of the binding*, both important features, which cannot fail to recommend them for use in Elementary Schools.

WRITING.

PHILIPS' SERIES OF HEAD LINE COPY BOOKS.

Philips' Caxton Copy Books.

Written and arranged by a Practical Teacher to meet the requirements of the New Code. In Twenty Books. Foolscap oblong 4to. Nos. 1 to 18, each 2d. Books 19 and 20, each 3d.

LIST OF THE SERIES.

STANDARD I.

1 ELEMENTS
Letters and Short Words
2 ELEMENTS
Long Letters and Easy Words
3 ELEMENTS
Long Letters and Easy Words

STANDARD II.

4 LARGE AND MEDIUM TEXT
Short Words and Figures
5 LARGE AND SMALL TEXT
Capitals and Proper Names
6 MEDIUM AND SMALL TEXT
Capitals and Figures

STANDARD III.

7 DOUBLE SMALL HAND AND SMALL TEXT
Easy Words and Sentences
8 DOUBLE SMALL HAND
Capitals, Figures and Sums
9 DOUBLE SMALL HAND
Capitals, Figures and Sums

STANDARD IV.

10 DOUBLE SMALL HAND AND TEXT
Geography of British Isles
11 SMALL HAND AND SMALL TEXT
Poetical Quotations, Figures & Sums
12 DOUBLE SMALL HAND
Poetical Quotations

STANDARD V.

13 SMALL HAND, LARGE AND SMALL TEXT
Geography of Europe and Figures
14 DOUBLE SMALL HAND
History of England
15 SMALL HAND
Geography of Asia

STANDARD VI.

16 SMALL HAND
Geography of America, Africa, and Australia
17 SMALL HAND
Biography and Poetry
18 SMALL HAND
Poetry

SUPPLEMENTARY BOOKS.

19 COMMERCIAL LETTERS, BILLS, RECEIPTS, &c.
20 COMMERCIAL ORDERS, INVOICES, DAY BOOK, LEDGER, &c.

Philips' Home and Colonial Copy Books.

Written and arranged by Alexander Stewart. In Fifteen Books. Foolscap 4to, each 2d.

LIST OF THE SERIES.

1 Initiatory Exercises
2 Letters & Combinations
3 Short Words
4 Capitals
5 Text Hand
6 Text and Round
7 Round Hand
8 Introduction to Small Hand
9 Round and Small Hand
10 Small Hand
11 Text, Round, and Small Hand.
12 Introduction to Ladies' Hand
13 Ladies' Hand
14 Commercial Sentences
15 Figures

NEW NUMBERS SPECIALLY PREPARED.

No. 6½. For **Standard 2.**—Text and Half-Text with Capitals.
No. 9½. For **Standard 3.**—Small Hand, Capitals and Figures.
No. 10½. For **Standard 4.**—Advanced Small Hand.

Philips' Progressive Series of School Copy Books,

Written and arranged by Alex. Stewart. F'cap 4to, Printed on Fine Cream Paper, each 2d. Fine edition, on Superfine Paper, each 3d.

LIST OF THE SERIES.

1 Initiatory Exercises
2 Alphabet in Progressive Order
3 Short Words
4 Large Hand
4½ Text Hand
5 Large and Round Hand
6 Round Hand
7 Introduction to Small Hand
7½ Introductory Book—Large, Round, and Small Hand
8 Round and Small Hand
9 Small Hand
10 Large, Round, and Small Hand
10½ Large, Text, Round, & Small Hand
11 Ladies' Small Hand
12 Commercial Small Hand
13 Figures
14 Introductory Book for Girls
15 Ladies' Angular Hand—First Book

Philips' Progressive Series of School Copy Books.

Written by Alexander Stewart. Post 4to, Printed on Fine Cream Wove Paper, each 4d. Demy 4to, Extra Superfine Series, each 6d. Large Post 4to Series, each 6d.

LIST OF THE SERIES.

1 Initiatory Exercises
2 Alphabet in Progressive
3 Short Words [Order
4 Large Hand
5 Large and Round Hand
6 Round Hand
7 Introduction to Small Hand
8 Round & Small Hand
9 Small Hand
10 Large, Round, and Small Hand
11 Ladies' Small Hand
12 Set of Commercial Sentences
13 Text Hand
14 Large, Text, Round and Small Hand

Philips' Victoria Copy Books.

With Engraved Head-lines, written and arranged by Alexander Stewart. An entirely New Series, in Twelve Books, oblong 4to, printed on Superfine extra thick Cream Wove Paper, each 3d.

LIST OF THE SERIES.

1 Initiatory Exercises
2 Alphabet in Progressive
3 Short Words [Order
4 Text Hand
5 Text and Round Hand
6 Round Hand
7 Introduction to Small Hand
8 Round and Small Hand
9 Small Hand
10 Text, Round, and Small Hand
11 Introduction to Ladies' Hand
12 Ladies' Small Hand

Philips' Series of Historical Copy Books.

In Twelve Books, Demy 4to, extra thick paper, each 6d.

LIST OF THE SERIES.

1 William the Conqueror, to Henry the First
2 Stephen, to Richard the First
3 John, to Edward the First
4 Edward the Second, to Richard the Second
5 Henry the Fourth, to Henry the Sixth
6 Edward the Fourth, to Richard the Third
7 Henry the Seventh, to Edward the Sixth
8 Mary, to James the First
9 Charles the First, to Charles the Second
10 James the Second, to Anne
11 George the First, to George the Third
12 George the Fourth, to Victoria

Philips' Series of Copy Slips,

Arranged and written by Alexander Stewart. Printed on Fine Cream Wove Paper, each 4d.

LIST OF THE SERIES.

1 Short Words
2 Large Hand
3 Round Hand
4 Introduction to Small Hand
5 Small Hand
6 Ladies' Small Hand
7 Text Hand

ARITHMETIC.

Piper's Advanced Arithmetic for Schools & Colleges, 3s. 6d.

"The reason and illustrations of the various rules are very fully given . . . . a special and most valuable feature."—*Scholastic World.*

Piper's Elementary Treatise on Arithmetic, 1s. 6d.

"The author's endeavour to make the study of arithmetic what it ought to be—a thorough mental training—is apparent on every page."—*Teacher's Assistant.*

Piper's Mental Arithmetic, 2s.

Piper's Introductory Mental Arithmetic, 6d.

"Mr. Piper's 'Mental Arithmetic' . . . has had a deserved success. . . . . Excellent instructions."—*School Guardian.*

GEOGRAPHY.

Class Book of Modern Geography,

By William Hughes, F.R.G.S. Foolscap 8vo, cloth, 3s. 6d.

*** "Philips' Comprehensive School Atlas" is designed to accompany this work.

Elementary Class Book of Modern Geography,

By William Hughes, F.R.G.S. Foolscap 8vo, 1s. 6d.

*** "Philips' Atlas for Beginners" is designed to accompany this work.

Hughes' Elementary Geography of England and Wales,

With Colored Map. *New edition.* Neat cover, 2d. Cloth, 3d.

Hughes' Elementary Geography of Scotland and Ireland,

With Maps. *New edition.* Neat cover, 2d. Cloth, 3d.

Hughes' Elementary Geography of Europe,

With Colored Map. *New edition.* Neat cover, 2d. Cloth, 3d.

Lawson's Outlines of Geography,

New edition, entirely re-written and extended. Cloth, 3s. 6d.

This book may also be had in Parts, viz :—

Part I.—The British Islands, 6d. | **Part III.**—Europe, 9d.
Part II.—The British Colonies, 6d. | **Part IV.**—Asia, Africa, America, 1s.

Lawson's Young Scholar's Geography.

Foolscap 8vo, stiff cover, 6d. Cloth, 9d.

*** This work is intended as a companion to "Philips' Initiatory Atlas."

Faunthorpe's Geography of the British Colonies and Foreign Possessions.

New edition, revised. Foolscap 8vo cloth, 2s.

*** Philips' "Atlas of the British Empire throughout the World" is designed to accompany this work.

British Colonies and Dependencies.

Compiled chiefly from the latest Official List. 8vo, printed on card, 1d.

Philips' Series of Geographies of the Counties of England and Wales,

For use in Schools, and adapted to the requirements of the New Code. F'cap 8vo, 32 pp., with Map, sewed, each 2d. Bound in cloth, with Colored Map, 4d. D'ble vols., 64 pp., with Maps, sewed, 4d. Bound in cloth, with Colored Map, 6d. List of the Series on application.

Crawley's Manual of British Historical Geography,

Foolscap 8vo, cloth, 2s.

Philips' Geography and History of the Counties of England and Wales.

A companion volume to Philips' "Handy County Atlas." Foolscap 8vo, cloth extra, 5s.

Bowden's Geographical Outlines of New Zealand,

With two Maps, and Examination Questions. Cloth, 1s.

Bowden's Manual of New Zealand Geography,

With Maps and Examination Questions. Foolscap 8vo, cloth, 3s. 6d.

PHYSICAL GEOGRAPHY.

Hughes' Class-Book of Physical Geography.

With numerous Diagrams and Examination Questions. *New edition* entirely re-written and extended, with a Map of the World. F'cap 8vo, cloth, 3s. 6d.

*** "Philips' School Atlas of Physical Geography" is designed to accompany this work.

Hughes' Elementary Class-Book of Physical Geography.

With Diagrams. Intended as a Companion Text-Book to "Philips' Physical Atlas for Beginners." Foolscap 8vo, cloth, 1s.

Lawson's Geography of River Systems. Cloth, 1s.

Lawson's Geography of Coast Lines. Cloth, 1s.

Maury's Physical Geography of the Sea.

New edition, with Addenda and numerous Illustrative Charts and Woodcuts. Crown 8vo, cloth, 5s.

HISTORY.

DAVIES' HISTORICAL MANUALS.

"Evidently the result of laborious research and extensive scholarship."—*The Head-master, Archbishop Tenison's School, London.*

Manuals of the History of England.

1. FROM THE DEATH OF EDWARD THE CONFESSOR TO THE DEATH OF KING JOHN (1066-1216). 2s.
2. FROM THE ACCESSION OF HENRY III. TO THE DEATH OF RICHARD III. (1216-1485). 2s.
3. THE TUDOR PERIOD (1485-1603). 2s.
4. THE STUART PERIOD (1603-1689). 1s. 6d.
5. FROM THE REIGN OF CHARLES I. TO THE END OF THE COMMONWEALTH (1640-1660). 1s. 6d.
6. FROM THE RESTORATION OF CHARLES II. TO THE REVOLUTION (1660-1688). 2s.
7. FROM THE ACCESSION OF JAMES I. TO THE BATTLE OF THE BOYNE (1603-1690). 2s.
8. FROM THE REVOLUTION OF 1688 TO THE DEATH OF QUEEN ANNE, 1714. 1s. 6d.
9. FROM THE ACCESSION OF WILLIAM III. TO THE ACCESSION OF GEORGE III. (1689-1760). 2s. 6d.
10. (*a*) FROM THE ACCESSION OF GEORGE III. TO THE BATTLE OF WATERLOO (1760-1815). 2s. 6d.
    (*b*) MANUAL OF ENGLISH LITERATURE FROM 1760-1815. 2s.

NOTE.—Nos. 3 and 4 also embrace the *Literature* of the Tudor and Stuart Periods respectively.

Brewer's Outlines of English History. 6d.

Crawley's Manual of British Historical Geography. 2s.

Curnow's English History for Schools and Colleges. 3s. 6d.

"Mr. Curnow's history shows accurate thought and learning."—*Christchurch Times.*

"A model English History."—*Literary World.*

"A very admirable review of English History."—*Lyttleton Times.*

GRAMMAR & SPELLING.

Brewer's Manual of English Grammar and Analysis of Sentences. 1s.

Brewer's Elementary English Grammar and Analysis. 4d.

Martin's Scholar's Handbook of English Etymology,

Prepared for the use of the Upper Standards of our Elementary Schools. Foolscap 8vo, stiff cover, 3d.

Jones's Spelling Book for Beginners. 6d.

Jones's Essentials of Spelling. 1s.

SCRIPTURE.

Bible Reading Lessons,

For Secular and other Schools. Edited by Thomas B. Bowden, B.A. Foolscap 8vo, strongly bound in cloth, viz:—

First Series, containing Selections from Genesis, History of the Jewish Nation from Egypt to the Settlement in the Land of Canaan, 1s.

Second Series, containing the History of the Jewish Nation from the Settlement in the Land of Canaan to the Return from Captivity in Babylon, 1s.

Third Series, containing Selections from the Psalms of David, Proverbs of Solomon, the Four Gospels, and the Acts of the Apostles, 1s.

Philips' Series of Scripture Manuals,

With full Explanatory Notes and Appendices.

"Very carefully done, and contains a large amount of information."—*School Guardian.*

"These Manuals have our heartiest commendation."—*Schoolmaster.*

"The notes are very full, and the matter is so arranged as to render great assistance to the student."—*Scholastic World.*

By the Rev. H. LINTON, M.A.

The Book of Nehemiah .... 1 6 | **The Book of Jeremiah** 2 0
The Book of Genesis 2 0

By the late JAMES DAVIES.

Notes on Genesis	1 0	**Notes on St. Matthew's Gospel**	2 0
Notes on Exodus.....	1 0	**Notes on St. Mark's Gospel.**	1 0
Notes on Joshua	1 0	**Notes on St. Luke's Gospel .**	1 6
Notes on Judges	1 0	**Notes on St. John's Gospel..**	2 6
Notes on I. Samuel.....	1 0	**Notes on the Acts of the Apostles**	1 6
Notes on II. Samuel	1 6	**Manual of the Church Catechism**	1 0
Notes on I. Kings	1 6		
Notes on II. Kings	1 6		
Notes on Ezra	1 0		

Manual of the Book of Common Prayer..... 2 0

MATHEMATICS.

Bain's First Grade Practical Geometry,

Containing—(*a*) all the necessary problems fully worked out, (*b*) test exercises on the same, (*c*) a series of graduated exercises for copying, and (*d*) all the First Grade Examination Papers given by the Department during the last three years. Price 3d.

"Well got up, the diagrams are clear."—*Schoolmaster.*

"Diagrams very clearly drawn."—*Scholastic World.*

"Instructions clear and precise."—*School Guardian.*

Martin's Elements of Euclid,

Containing the First Six Books, with a Selection of Geometrical Problems for Solution, to which are added the Parts of the Eleventh and Twelfth Books. Crown 8vo, cloth, 3s. 6d.

Martin's Euclid,

With a Selection of Geometrical Problems for Solution. Crown 8vo, Book I., cloth, 1s.; Books I. and II. 1s. 6d.

Martin's Graduated Course of Problems on Practical Plane and Solid Geometry,

With Miscellaneous Exercises in Practical Plane and Solid Geometry, Etymology of Geometrical Terms, &c. Crown 8vo, cloth, 3s. 6d.

Whitworth's "Standard" Algebra,

Foolscap 8vo, stiff cover, 6d. Cloth, 9d.

SCIENCE.

Piper's Acoustics, Light, and Heat,

With numerous Illustrations, price 2s. 6d.

"By far the best and clearest elementary treatise on the subject."—*The Principal, Training College, York.*

"Very suitable for the use of science classes."—*The Principal, Training College, Ripon.*

Class Book of Inorganic Chemistry. In preparation.

Hutton's Class Book of Elementary Geology, 1s. 6d.

Hewitt's Class Book of Elementary Mechanics,

Part I.—Matter. With Illustrations, price 1s. 6d.

DRAWING.

Philips' Series of Drawing Books.

Simple Studies in Straight Line and Perspective, in Seven Books, each 3d.; the Set, bound in cloth, 2s. 6d.

Easy Landscapes. First Series, in Six Books, each 3d.; the Set, bound in cloth, 2s. 6d.

Easy Landscapes. Second Series, in Six Books, each 3d.; the Set, bound in cloth, 2s. 6d. *Blank Books for use with above, each* 3d.

Philips' Landscape Drawing Studies, from Original Sketches. 4s.

Architectural Drawing Studies.

Intended as a Simple Guide to the knowledge of Ancient Styles of Architecture; by Alfred Rimmer. With an Introduction by the Rev. J. S. Howson, D.D., Dean of Chester. Imperial 4to, boards, 2s. 6d.; cloth elegant, gilt edges, 5s.

Easy Course of Perspective.

Preparatory to Free-Hand Drawing and Sketching from Nature, for the use of Schools. By J. I. Kiddle, King William's College, Isle of Man. Oblong folio, stiff cover, 2s.

Artist's Assistant,

A Series of Proportioned Letters in various Styles. Royal oblong 8vo, stiff cover, 1s. 6d.

MUSIC.

Taylor's Student's Text Book of the Science of Music.

For use in Colleges and Schools. 6s.

"This is a good and sound book, which cannot fail to recommend itself to the earnest musical student."—*Literary World.*

"We know of no book on the theory of music which is in itself so elaborate and yet so complete; which embraces so many subjects, nor which is more comprehensible."—*The London Figaro.*

"It is rare that we have seen a more complete and well arranged text book."—*Music Trades Review.*

Taylor's Manual of Vocal Music.

Being a complete Guide to Singing at Sight. 1s. 6d.

A Certificated Teacher writes:—"I cannot imagine a teacher having any trouble with the 'Music Difficulty' if he uses this Manual."

"One of the best books for young students that have been published."—*Scotsman.*

"We may especially draw attention to the section headed 'Directions for the Conduct of a Practical Singing Lesson,' which contains much sound and valuable advice to teachers."—*Musical Times.*

"The directions for conducting a class are admirable."—*Choir.*

Taylor's Choice Secular School Songs,

With an Introduction for the use of Teachers. 3d.

Taylor's Child's First Catechism of Music. 2d.

Philips' Music Sheets,

For use in connection with Taylor's "Manual of Vocal Music," and for general purposes of Musical Instruction. Printed in two colours. Size—33 by 44 inches. The set of 15 sheets complete, £1 10s. Or mounted on cloth, £2 12s. 6d.

These sheets, which are unique of their kind, being produced on a larger scale than has hitherto been attempted, and printed in two colours for the sake of clearness when used with large classes, proceed in order from the earliest rudiments, and afford material for the full explanation of any musical passage.

GEOGRAPHICAL CLASS BOOKS.

	s.	d.
A CLASS-BOOK OF MODERN GEOGRAPHY, with Examination Questions, by William Hughes, F.R.G.S. Foolscap 8vo, cloth...	3	6
AN ELEMENTARY CLASS-BOOK OF MODERN GEOGRAPHY, by William Hughes, F.R.G.S. Foolscap 8vo, cloth	1	6
A CLASS-BOOK OF PHYSICAL GEOGRAPHY, with numerous Diagrams and Examination Questions, by William Hughes, F.R.G.S. Foolscap 8vo, cloth ...	3	6
AN ELEMENTARY CLASS-BOOK OF PHYSICAL GEOGRAPHY, with Diagrams, by William Hughes, F.R.G.S. Intended as a Companion Text Book to "Philips' Physical Atlas for Beginners." Foolscap 8vo, cloth, lettered	1	0
ELEMENTARY GEOGRAPHY OF EUROPE, with a Map. By William Hughes, F.R.G.S. Imperial 32mo, neat cover, 2d., or in cloth...	0	3
ELEMENTARY GEOGRAPHY OF ENGLAND AND WALES, with a Map. By William Hughes, F.R.G.S. Imperial 32mo, neat cover, 2d., or in cloth	0	3
ELEMENTARY GEOGRAPHY OF SCOTLAND AND IRELAND, with Maps. By William Hughes, F.R.G.S. Imperial 32mo, neat cover, 2d., or in cloth	0	3
OUTLINES OF GEOGRAPHY, FOR SCHOOLS AND COLLEGES, by William Lawson, St. Mark's College, Chelsea. Foolscap 8vo, cloth	3	6
THE GEOGRAPHY OF RIVER SYSTEMS, by William Lawson, St. Mark's College, Chelsea. Foolscap 8vo, cloth	1	0
THE GEOGRAPHY OF COAST LINES, by William Lawson, St. Mark's College, Chelsea. Foolscap 8vo, cloth	1	0
THE YOUNG SCHOLAR'S GEOGRAPHY, by William Lawson. Foolscap 8vo, stiff cover, 6d., cloth	0	9
A MANUAL OF HISTORICAL GEOGRAPHY, for the use of Civil Service Students, Training Colleges, &c. By W. J. C. Crawley, B.A. Foolscap 8vo, cloth ...	2	0

George Philip and Son, Publishers, London and Liverpool.

EDUCATIONAL MAPS.

PHILIPS' SERIES OF LARGE SCHOOL-ROOM MAPS.

With the Physical Features boldly and distinctly delineated, and the Political Boundaries carefully colored. Size—5 feet 8 inches by 4 feet 6 inches. Mounted on rollers and varnished. Constructed by William Hughes, F.R.G.S.

LIST OF THE MAPS.

Price 16s. each.

THE WORLD, IN HEMISPHERES
EUROPE
ASIA
AFRICA
NORTH AMERICA
SOUTH AMERICA
AUSTRALIA AND NEW ZEALAND
NEW SOUTH WALES
ENGLAND AND WALES
SCOTLAND
IRELAND
PALESTINE
INDIA

Price 21s. each.

THE WORLD, ON MERCATOR'S PROJECTION
BRITISH ISLANDS
NEW ZEALAND
OCEANIA

PHILIPS' SMALLER SERIES OF SCHOOL-ROOM MAPS.

Size—3 feet by 2 feet 6 inches.

Mounted on rollers and varnished, each 7s. 6d.

LIST OF THE MAPS.

EASTERN HEMISPHERE
WESTERN HEMISPHERE
EUROPE
ASIA
AFRICA
NORTH AMERICA
SOUTH AMERICA
AUSTRALIA
NEW ZEALAND
ENGLAND AND WALES
SCOTLAND
IRELAND
PALESTINE
WANDERINGS OF THE ISRAELITES

The above are reductions of the large series, constructed by William Hughes, F.R.G.S., and are designed for use in Private Schools and Families. They are clearly and distinctly engraved, and embody an amount of information not to be had in any similar series of Maps.

George Philip and Son, Publishers, London and Liverpool.

753-BAC-107